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QUESTIONS

ON

GENERAL PHYSICS

BASED ON THE TENTH EDITION OF EVERETT'S TRANSLATION OF

DESCHANEL'S NATURAL PHILOSOPHY

BY HAROLD WHITING, PH.D.

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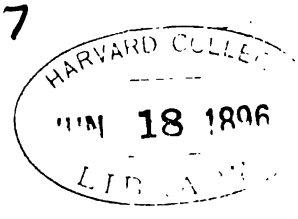

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PREFACE.

This book contains a collection of questions, suggested for the most part by the text of Deschanel's Natural Philosophy. It is intended, as stated below, for the use of students in connection with a course in "General Physics," which has been given for several years in the University of California. Alternate pages have been left blank, in order that students may make notes enabling them to recall certain passages of the text, together with supplementary remarks or comments made in the lectures. By examining a student's notes from time to time, it is obviously possible to ascertain whether he has or has not been following the work of the course.

In making use of these questions as a basis for recitations and lectures, the author insists that students must review by themselves (if necessary) such subjects as are required for entrance to the University. Elementary topics are not, accordingly, discussed in the class-room, except in so far as they may be necessary to continuity of thought. Students are expected to recite upon the subject matter of their text-book, in so far as indicated by references thereto, and to be prepared for examination upon *all* questions included in the course. It is understood that the written examinations are not limited to these questions, but only to the *topics* which they cover. These topics constitute, none the less, a comparatively limited ground, upon which, accordingly, thorough preparation may be expected and required.

It is thought that other students, who desire to review the subject of physics, may derive help from writing out the answers to such questions as are treated by Deschanel, and comparing their answers with the text-book. For this reason, a few more copies have been printed than were actually required for this and next year, a period beyond which the use of this book was not originally contemplated.

PREFACE.

The principal feature of this book is the minute classification of questions according to topics. Care has been taken to make these questions exhaustive, by cross references when necessary, in so far as concerns the limited ground which they cover. Attention has been called in many cases to tacit assumptions, without which certain well known conclusions cannot be reached; and to simple mathematical demonstrations of important propositions, which the student is usually left to take for granted, or to work out for himself.

When the book has been laid aside for class purposes, it may still perhaps be useful to teachers as a basis for preparing papers for written examinations.

As these questions have been prepared and the proofs read under press of work, it is feared that they are by no means free either from typographical errors, or from errors of composition, such as the interchange of the words "spent" and "utilized" in Question 2, page 48. The author will be glad to receive, from any source, corrections or suggestions which may be of service in preparing a table of errata and addenda, and to send such a table, when completed, to any person desiring to use it.

HAROLD WHITING.

BERKELEY, CALIFORNIA,

August 13th, 1894.

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QUESTIONS ON GENERAL PHYSICS.

INTRODUCTORY.

The following questions have been prepared for the use of college students in connection with a lecture and laboratory course in General Physics. The asterisk (*) indicates topics with which the student should be already familiar in his preparatory work. The dagger (†) indicates topics to be treated or supplemented in the course of lectures. The double dagger (‡) indicates topics illustrated by experiments either in the lecture-room or in the laboratory. Questions containing problems to be solved by the student are marked "Prob." References are as follows: D., to sections in DESCHANEL'S Natural Philosophy, translated by EVERETT, tenth edition; L., to laboratory exercises; Q., to questions in the list immediately preceding the reference, unless otherwise indicated by section or number. References which are incomplete, and explanatory remarks, which may be omitted in recitation, are enclosed in parentheses.

1.† State certain rules for expression to be observed in note-books and in recitation.

2. State the distinction between "Natural" (or "Physical") phenomena and other phenomena. In which does observation play the more important part? D. 1.

3.† Show that "Science," even in its most general sense, necessarily involves classification or arrangement of some sort.

4. Explain the principles upon which Natural (or Physical) Science has been divided broadly into Natural History and Natural Philosophy. In which of these divisions does classification, and in which does the study of cause and effect receive the relatively greater amount of attention? D. 1.

5. Upon what farther principles has Natural Philosophy been divided into Astronomy, Biology, Chemistry, and Physics, (or Natural Philosophy in its more restricted sense)? D. 2.

6.† To which of the above divisions is the Experimental Method virtually restricted, and in what does the Experimental Method consist?

7. Should the descriptive portions of Astronomy, Biology, and Chemistry (*e.g.*, Mineralogy) be included under Natural Philosophy or under Natural History? Q. I. 4.

8.† Distinguish ordinary descriptive physics, whether studied in the class-room or in the laboratory, from general physics (whether mathematical or simply deductive), on the one hand and from truly experimental (inductive) physics, including physical investigation and measurement, on the other hand.

9.† Show that, from the nature of the subjects allotted to Physics, this science is able to carry both inductive and deductive methods farther than any other science.

10.† What faculty is particularly trained by quantitative experiments or measurements?

11.† State some of the advantages of a course in general and experimental physics. Show that such a course trains the faculties of expression, observation, classification, experimentation, inference, explanation, and judgment (the last three being the most important branches of reasoning, viz., inductive, deductive, and quantitative).

12.*†Name the principal branches of Physics. Explain the following terms and their mutual relations: Dynamics, Kinetics, Statics, Mechanics, Hydrostatics, Pneumatics, Thermics, Optics, Acoustics, Electricity and Magnetism. D. 3 and 9.

1.* Define the foot and the metre.

2.* Explain the use of a graduated scale for measuring length.

3.* Define the pound and the gram as units of mass. D. 160.

4.* Explain the construction and use of a set of weights (with the method of substitution).

5.* Define the (mean solar) second.

6.* Explain the use and construction of a clock.

7.* Define velocity, and state in what units it is expressed.

8.* Define the area of a surface, and name different units of area.

9.* Find the area of a plane rectangular surface of length, l, and breadth, b.

10.* Define volume, and state in what units it is expressed.

11.* Find the volume of a block of length, l, breadth, b, and thickness, t.

12.* Define density, and give an example. D. 160.

13.* Distinguish absolute and relative density. D. 160.

14.* Find the density, d, of a body of mass, m, and volume, v. (D. 160.)

15.* Find the mass, m, of a body of density, d, and volume, v. D. 160.

16.* Find the volume, v, of a body of mass, m, and density, d. (D. 160.)

17.*‡ Discuss the experimental determination of the density (1) of a solid, (2) of a liquid, and (3) of a gas, by direct measurements of mass and linear dimensions, and show that the same fundamental principles apply to each case. (D. 162.)

18.* Define the pound weight and the gram weight as units of force (in latitude 45°). D. 161.

19.* Explain the signification and use of the prefixes, mega-, kilo-, hekto-, deka-, deci-, centi-, milli-, and micro-.

20.* Explain the signification of the hyphen in such words as foot-pound, kilogram-metre, etc.

21.* Explain the signification of "per" in such expressions as pounds per square inch, or centimetres per second.

II.

CRUDE IDEAS OF FORCE.

1.† Show that the sense of touch is closely connected with our ideas of force.

2. What connection exists, in general, between force and the muscular effort necessary to produce or to resist it? D. 7.

3.† Name certain cases in which the maintenance of a force, like continued muscular effort, requires the continuous expenditure of energy of some sort; and where, if the source of energy be cut off, exhaustion ensues, and the force ceases.

4.† What is meant by the "fatigue" of metals, etc., under continued strain? Would a perfect solid exhibit such effects?

5.† Are we justified in supposing that the maintenance of inanimate forces in general, like the maintenance of muscular tension, in the absence of a fresh supply of energy, necessarily involves fatigue or exhaustion to any considerable extent? Illustrate by the force of gravity upon the moon.

6.† What misconception is likely to arise from the use of muscular tension as the type of a force?

7.† Does the modern idea of force contain any reference to the supply of energy by which it may happen to be maintained?

8.† What restriction, not observed by earlier writers, exists in the modern use of the word force?

9.† Criticise the expressions, force of a waterfall, force of the wind, force of gravity.

10.† Consider a "push," a "pull," or a "shove" as instances of a force. What does each imply as to the direction of the force with respect to the agent; as to the point of application of the force, and as to the state of tension or compression produced?

11.† Criticise the definition of a force as a "push or a pull." (HALL'S Elementary Ideas.) To what extent is it supposed that molecular forces can be so classified? Is it thought that electromagnetic forces fall into either category?

III.

FORCE RELATED TO DISPLACEMENT.

1.† What in general is the effect of a force upon a point in an elastic body?

2.† What relation exists by definition between the direction of the force and the direction of the displacement which it produces in a homogeneous elastic medium?

3.† What obvious quantitative relation exists by definition between the magnitudes of several forces acting in a given direction and the magnitude of the resulting force?

4.‡ Describe one or more experiments showing that the displacement produced by two or more forces acting at a given point in the same direction is the sum of the displacements produced by the separate forces when acting alone.

5.† State how forces are measured (relatively) in Statics, and upon what experimental evidence the accuracy of this measurement depends.

6.† Explain HOOKE'S law, *ut tensio, sic vis.*

7. What is meant by a "dynamometer?" D. 7.

8. Name some form of dynamometer in common use. D. 7.

9.* Describe an ordinary "spring balance." D. 7.

10.‡ Describe the calibration of a "spring balance."

11.* Explain the use of a "spring balance" for the measurement of forces.

IV.

GRAVITATION UNITS OF FORCE.

1. Distinguish between the uses of the word "weight" in the sense of "mass" and in the sense of "force." Which use is adopted by most modern writers? D. 161.

2. What name is given to such units of force as the pound-weight, or the weight of a kilogram? D. 8.

3. What are meant by gravitation units of force? D. 8.

4.† Describe an experiment with an ordinary balance showing that the weight of a body at the top of a high tower is less than at the foot of the tower.

5.† What inference concerning the constancy of gravity is drawn from the behavior of clocks controlled by gravity pendulums when transported from one latitude to another?

6.† What inference concerning the constancy of the action of springs is drawn from the behavior of chronometers with balance-wheels controlled by hair-springs when transported from one latitude to another?

7.† State the result of testing the weight of a given body in different latitudes by means of a spring balance.

8. Explain the result of testing the weight (?) of a given body in different latitudes by means of an ordinary balance. D. 161.

9. In an unknown latitude, what kind of balance would you prefer for measuring "weight" in each of its two senses? Q.

10. In what sense of the word *weight* may it be said to be constant, and in what sense to vary with the latitude? Q.

11. Is the variation in gravitation units of force with latitude or altitude sufficient to impair their commercial value? D. 8.

V.

ABSOLUTE UNITS OF FORCE.

1.† What is meant by an "absolute unit of force?" Explain by the action of such a unit upon a spring balance in different latitudes.

2.† Discuss the possibility of graduating a spring balance so as to indicate the magnitudes of forces in absolute units.

3.† Name the absolute units of force adopted in the English and in the Metric Systems.

4.† Define the "poundal" in terms of the weight of a pound in latitude 45 degrees, where the velocity acquired by a falling body in one second is 32.172 feet per second.

5.† Define the "dyne" in terms of the weight of a "gram" in latitude 45 degrees, where the velocity acquired by a falling body in one second is 980.61 centimetres per second: the equivalent of 32.172 feet per second.

6.† Give instances of familiar forces measured in poundals and in dynes.

7. In latitude 45 degrees, how would you reduce grams to dynes? pounds to poundals? and the reverse? Q.

8.† What branch of Physics has been greatly simplified by the use of absolute units of force?

VI.

SPECIFICATION OF A FORCE.

1. Can a force be applied practically to a point? Give reasons for your answer. D. 12.

2.* What is meant by the point of application of a force? D. 11.

3. What is meant by the line of action of a force? Is the line of action of a force synonymous with the direction of the force? D. 13.

4.* What is meant by the magnitude of a force?

5. What elements are necessary for the specification of a force? Q.

6. Correct DESCHANEL'S statement that "a force is completely specified when its magnitude, its point of application and its line of action are all given." State what interpretation must be given to the words "line of action" in this statement in order that it may be true, and whether this interpretation is or is not in keeping with his use of the expression? D. 11 and 13.

VII.

COMPOSITION AND RESOLUTION OF FORCES MEETING AT A POINT.

1.‡ Describe an experiment showing that the direction and magnitude of the displacement produced by a given force acting on a point in a homogeneous elastic medium is independent of the forces already existing at that point, provided that these forces are constant in magnitude and in direction.

2. Show that all geometrical propositions relating to displacements apply also to the forces which these displacements represent. Q.

3. Two forces acting on a point produce independently the displacements, AB and BC. What is the resulting displacement? Q.

4. What name is given to a single force which will, acting alone, produce the same displacement as two or more than two other forces when acting together? D. 15.

5. Define the resultant of two or more forces. D. 15.

6.† Show that, if forces are measured by the displacements which they produce, the resultant of two forces is represented in direction and magnitude by the diagonal of a parallelogram, the sides of which represent the two forces in question. Q.

7.* Describe the "parallelogram of forces," and its use in finding resultants. D. 16.

8.* Show that two forces, represented by the lines AB and BC, have a resultant represented by a line, AC, in the same plane as AB and BC. D. 14, 15.

9.* Explain the "triangle of forces," its relation to the "parallelogram of forces," and its use in finding resultants. D. 16.

10. Show that any number of forces, AB, BC, CD, . . . YZ, have a resultant, AZ. D. 18.

11.† Consider whether the statement in the last question applies to forces in one plane only, or to forces in any plane.

12. Show that the resultant of three forces represented by the lines, *AB*, *BC*, and *CD*, is represented by the diagonal of the parallelopiped constructed on these three lines. D. 18.

13. Show that in the parallelopiped of forces, the order of combination is indifferent. D. 18.

14. Describe the use of the parallelopiped of forces for finding resultants of three forces. D. 18.

15.* What name is given to two or more forces which together produce the same displacement as a single force of given magnitude and direction? D. 15, 21.

16.* Define the word *component*. D. 15, 31.

17. Show that if the magnitude and direction of a force and two of its three components are given, the magnitude and direction of the remaining component is determined. Q.

18. Show that, if the magnitude and direction of a force and the direction of its three components are given, the magnitude of each component is determined. Q.

19.* What name is given to the process of finding the components of a force in two or three different directions? D. 31.

20. Show that a force may in general be resolved into components, if these components are unlimited either in number or in direction, in an infinite number of ways. Q.

21. Name certain circumstances under which the resolution of a force into components leads to definite results. D. 31, Q.

22.* State certain necessary limitations between the magnitude of the resultant of two forces and (the sum and difference of) these forces; also between the sum and the resultant of any number of forces. Q.

23. What name is given to components of a force when these are at right angles to each other? and to the process of resolution in such cases? D. 32.

24. What kind of composition and what kind of resolution is understood unless otherwise stated? D. 32.

25. Show that a force can have three and only three rectangular components, and that it is completely specified when, and only when, these three components are explicitly or implicitly given. Q.

26. Find by the Pythagorean proposition the relation between a force and its three rectangular components. Q.

27. A point, A, is displaced from A' to A'', find (by rectangular projection) how much it has approached an infinitely distant point, B. Prob.

28. What is meant by the (rectangular) component of a displacement or a force in or along a given direction, line, or plane? D. 32.

29. State the trigonometric relation between a force AB, and its (rectangular) component along the line, AC. D. 32.

30. What in general is the trigonometric relation between a force and its component in a line (or plane) making the angle A with a line parallel to the direction of the force? D. 32.

31. Show that a force can have no (rectangular) component in a direction at right-angles with itself. Q.

32. Show that the component of a displacement in a given direction is determined solely by the component of the force in that direction, and is not affected by either of the other two components. Q.

33. Show that the component displacement in any direction due to one of the components of a force acting alone in this direction is the same as that due to the whole force. Q.

VIII.

EQUILIBRIUM OF FORCES MEETING AT A POINT.

1. When is a point in an elastic body said to be in equilibrium under the action of forces estimated by the displacements which they produce? D. 9.

2. Show that a point in an elastic body is in equilibrium if the resultant of all the forces acting upon it is zero. Q.

3.† State the result of plotting lines, *AB*, *BC*, *CD*, *DE*, etc., so as to represent in magnitude and direction forces producing equilibrium at a point.

4.† What is meant by the "polygon of forces?"

5.* When are three forces acting at a point in equilibrium? D. 14.

6.* Show that three forces acting at a point cannot be in equilibrium unless they are contained in the same plane. Q.

7.* Explain the "triangle of forces" as applied to forces in equilibrium. D. 14.

8.‡ Explain the determination of the weight of a body by means of two spring balances with cords meeting in a knot from which the body is suspended, and illustrate by examples. L.

9.‡ Explain the determination of the weight of a body suspended by a cord by means of a spring balance acting upon a knot in this cord, so as to produce a known angular deflection. L.

10. How do you find the relative magnitudes of three forces of known direction, producing equilibrium at a point?

11.† What is meant by the "equilibrant" of a number of forces?

12.† Find the equilibrant of the forces, *AB*, *BC*, . . *YZ*. Q.

13. Find the equilibrant of two forces, *AB* and *BC*, and show that it lies in the plane of these forces. D. 14.

14. Show that in the triangle of forces the forces and their equilibrant represent rotation in the same direction about any point in the interior of the triangle. D. 14.

15. Show that the equilibrant of any number of forces is in all cases equal and opposite to their resultant. Q.

IX.

ACTION AND REACTION.

1. A small light spring of the normal length, $A'B'$, is stretched to the new length, $A''B''$. Find the displacement of B relatively to A, and the displacement of A relatively to B, (1st) taking AB as the positive direction, and (2d) taking BA as the positive direction. What obvious relations exist between the magnitudes and between the signs of these four displacements? Prob.

2. Show that a force, if represented by a relative displacement, necessarily exists in four different aspects. Q. 1.

3.† When a small light spring is stretched from the normal length, $A'B'$, to a new length, $A''B''$, what displacement is taken as a measure of the force exerted upon the spring by B? by the spring at B? upon the spring at A? by the spring at A?

4.† Consider the modifications (if any) which would be introduced into your answers to the questions above by the substitution of compression for extension.

5. What relation exists by definition between the forces exerted at a given point upon and by a given thing (or agent)? Q.

6.* Considering the force exerted by a spring upon a fixed support as the "action" of the spring, what name is given to the force exerted by the support upon the spring?

7.* Considering the force exerted by any agent (the hand, for instance), upon a spring as the "action" of that agent, what name is given to the force exerted by the spring upon the agent?

8.* If by the action of a spring, AB, we mean the force exerted by it at A, what name do we give to the force exerted by it at B?

9.* If by the action of any agent upon a spring, AB, we mean the force exerted upon the spring at A, what name do we give to the force exerted upon the spring at B?

10.† Distinguish action and reaction exerted at a point from action and reaction exerted through some medium (for instance, a spring) at two different points.

11.† Show that action and reaction are (in each case) names for two different aspects of one and the same stress.

12.† Show that action and reaction in an elastic body, being measured by relative displacement, are equal and opposite whether that body be at rest, in uniform motion, or under acceleration.

13.† Show that action and reaction are necessarily simultaneous.

14.*†State the principle of action and reaction.

15.* Give instances of action and reaction. D. 10.

16.* Correct the following statement: "every action is followed (!) by an equal and opposite reaction." Q.

17.* Contrast the scientific use of the word "reaction" with its popular use, exemplified in the phrase, "reaction of public opinion." Q.

18.* Criticise the illustration of action and reaction by the successive swings of a pendulum. Q.

19.† In applying the principle of action and reaction to astronomical phenomena, what assumption is made with respect to the velocity of propagation of gravity? Q.

20. Why cannot the principle of action and reaction be applied indiscriminately (as in D. 10) to forces which, like mechanical stresses (*e.g.* the tension of a cord) or like magnetic attractions and repulsions, require (in some cases) a perceptible amount of time for their propagation? Q.

21.† Show that certain objections to the principle of action and reaction disappear if the forces in question are applied at (or indefinitely near) the same place.

22.* Apply the principle of action and reaction to the pressure between a body and the table upon which it rests; to the force exerted by the hand in pulling a rope; to the tension between the two halves of a rope during the "tug of war"; to the pull of traces upon a whiffletree in starting a wagon, etc., etc. State accurately what constitutes the pair of equal and opposite forces in each case.

23.† Show that the action and reaction between two bodies, though equal and opposite, being applied to different bodies, do not tend to produce equilibrium in either, considered by itself.

X.

TRANSMISSIBILITY OF FORCE.

1.† Describe an experiment with a chain of light spring balances illustrating the transmission of force.

2.† Prove, by the principle of action and reaction, that force is transmitted along a chain of light spring balances without loss.

3.† Show, by considering a medium transmitting force as a sort of chain, that the equality of action and reaction can be predicated for every point in the medium.

4.† Describe one or more cases of the transmission of force between two points in a light rigid body.

5.‡ Describe one or more experiments illustrating the transmission of force by a cord, or other flexible substance.

6.* Criticise the reason usually assigned (loss of force) for hitching a horse as close as possible to his load. Q.

7. What relation exists between the forces at various points of a line, AB, any one of which would be neutralized by a given force at A, in the line, AB? (Axiom).

8.† Show that a force of given magnitude in the direction, AB, may be transferred to any point, B, in its line of action without modifying the result. D. 13.

9.‡ Describe one or more experiments with a rigid body held by elastic forces, or otherwise, so as to be sensitive to any change in the magnitude, as well as in the direction or line of action of a force, and state the effect of changing the point of application of a given force along its line of action.

10.* What is meant by the transmissibility of a force along its line of action? D. 13, Q.

11.† Show that the line of action of a force may be substituted for its point of application in all cases involving only a single position of a body, and not concerning the displacement of the point itself. Q.

EQUILIBRIUM OF FORCES ACTING AT TWO POINTS.

1. What is meant by a "rigid body" in mechanics? D. 12.

2.† What is meant by a "strut" or a "tie"? and what kind of force is each most suitable for transmitting?

3.† What relation is found (experimentally) to exist between the forces transmitted by a strut or a tie, and the line joining the points of application of these forces?

4.* Show, by general considerations of symmetry, that two equal and opposite forces applied at two points, A and B, of a rigid body, parallel to AB, should produce no displacement (either of translation or of rotation) in the body as a whole.

5.† When is a rigid body said to be in equilibrium? D. 9.

6. State the (three) conditions of equilibrium of two forces applied at two points in a rigid body. D. 13.

7. State the conditions of equilibrium of any number of forces with a common line of action. D. 13.

XII.—TRANSLATION AND ROTATION.

1.* Distinguish displacements, (whether produced by forces or not) into two classes, according to whether translation or rotation is produced. D. 5.

2.† Describe an experiment with a globe illustrating the fact that all displacements are resolvable into translation combined with rotation about one or more axes.

3. Show that the displacement of a body is completely specified by that of the centre and two points on the surface of a sphere in which it is included. Prob.

4.† Show (by drawing great circles through any two points, A and B, on the surface of a sphere, before and after rotation) that there must be two antipodal points, (the intersections of the great circles) which are not affected by any given displacement of a spherical surface about its centre.

5. Show that every displacement of a body about a point in it must have a definite axis. Q. 4.

6. Show that every displacement must be resolvable into one of translation, combined with one of rotation about a given axis. Q. 4, 5.

XIII.

COMPOSITION AND RESOLUTION OF COUPLES IN THE SAME PLANE.

1.* Distinguish a push or a pull from a twist, torsion from tension or compression, according to the displacement produced. D. 5 and 6.

2.* State the effect of two equal and opposite forces applied at the points, A and B, at right angles with the line, AB, in an elastic medium.

3.* What combination of forces is necessary to produce a twist?

4. What name is given to a pair of equal and opposite forces having different lines of action? to any combination of forces producing a twist? D. 26, 27.

5. Define the word "couple," and tell what is meant by the "arm," the "moment," the "plane," and the "axis" of the couple. D. 26, 27.

6.† Distinguish right and left-handed couples: also similar and opposite couples.

7.† Show that two equal and opposite couples in the same plane, having equal forces and equal arms not parallel, give rise to a pair of equal and opposite resultants, having for their common line of action a diagonal of the parallelogram formed by the prolongation of the component forces, and, therefore, neutralize each other, as far as rotatation or twist is concerned.

8. Show that two similar couples in the same plane, with equal forces and arms, being capable of neutralizing the effect of a given couple, are equivalent to each other. (Axiom).

9.‡ Describe one or more experiments showing that the translation or rotation of a couple in its own plane does not modify the effect which it produces.

10. Find the resultant of two similar couples with equal forces and with arms, AB and BC, in the same straight line. Prob.

11. What assumption is made in the last question as to the disappearance of two equal and opposite forces at a point? and what postulate (as to the introduction of equal and opposite forces at a point) will enable you to resolve the resultant couple back into its components? Prob.

12.† Show that a couple with given forces and arm, A, may be resolved into A couples with the same forces, but with unit arms.

13.† Show that a couple with given arm and forces, F, can be resolved into F couples with the same arm, but with unit forces.

14.† Show that a couple with forces, F, and arm, A, can be resolved into $F \times A$ couples with unit forces and arms. Q. 12, 13.

15. What name is given to the product of the force and arm of a couple? D. 26.

16.† Describe one or more experiments with a torsion apparatus showing that the effect of a couple is proportional to the force, if the arm is constant; to the arm, if the force is constant; and to the moment, if the force and arm both vary. State the (empirical) law established by these experiments.

17. State the necessary relation existing between the moment of a couple and the twist produced in an elastic medium, in which a given couple always produces a given additional twist. Prob.

18. Show (by resolution into unit couples) that the resultant of any number of couples in the same plane is a single couple in that plane, with moment equal to the algebraic sum of the moments of the components. Q.

19.† Show that a couple can be balanced only by an equal and opposite couple. D. 27.

20.‡ Describe one or more experiments (with E. H. HALL'S apparatus) illustrating the conditions of equilibrium of two couples in the same plane.

21.† State the conditions of equilibrium of two or more couples in the same plane. D. 27.

22. What is meant by the moment of a force about a point? D. 24.

23.† Show that the moment of a couple is equal to the difference (or algebraic sum) of the moments of its two forces about any point in its plane.

24.† Apply the principle of moments about a point to the case of equilibrium as to rotation about this point.

XIV.

COMPOSITION OF A FORCE AND A COUPLE IN THE SAME PLANE.

1. Show that a change in the line of action of a force is equivalent to the introduction of a couple whose moment is the product of the force and the distance between its old and new lines of action, and whose plane contains these lines. D. 28.

2. Find the direction of rotation introduced by the displacement of the points of application of forces in special cases, (*e.g.*, a right-handed displacement of a downward force). Prob.

3.† The point of application of a force of magnitude and direction, AB, is moved through a distance, AC, at right-angles to AB; find the nature of the action which brings this about, and the complete specifications for this action.

4.† Show, conversely, that the resultant of any force and any couple in the same plane is a single force in this plane, equal in magnitude to the component force, parallel to this force, and at a (perpendicular) distance from it, equal to the quotient of the moment of the couple by the magnitude of the force.

5. How would you construct a couple equivalent to a given couple, so as to show that its effect upon a given force in its own plane is simply to displace the line of action of this force? D. 28.

6. Find the direction of the displacement produced in the points of application of forces by couples in special cases, (*e.g.*, a left-handed couple and an upward force). Prob.

XV.

COMPOSITION OF PARALLEL FORCES.

1. Show that the transfer of two equal forces, having the same direction, to a line midway between them is equivalent to the introduction of two equal and opposite couples, and hence does not affect the result. Q. XIV.

2. Show that the resultant of two equal forces in the same direction is equal to the sum of these forces, acting always in a line midway between the lines of action of the components. Q.

3.† Show that the transfer of any two forces, AX and BY, having the same direction, to a common point, P, dividing the line, AB, into parts such that $AP \times AX$ is equal to $BP \times BY$, being equivalent to the introduction of equal and opposite couples, does not modify the result.

4.† Extend the demonstration called for in the last question to the case of any two unequal forces in opposite directions.

5.† Show that the resultant of any two forces having the same direction is a single force in the same direction, equal in magnitude to the sum of the component forces, with its line of action in the same plane with, and between the lines of action of these forces, and distant from the line of action of each in the inverse proportion of the magnitudes of these forces. D. 20.

6. Specify the resultant of two unequal parallel forces in opposite directions. D. 20, Q.

7. Compare the moments of two parallel forces about any point in their plane with the moment of their resultant about this point. D, 22, 24.

8. Show (by successive composition) that any number of parallel forces, whose algebraic sum is not zero, must have a single force for their resultant. Prob.

XVI.

EQUILIBRIUM OF THREE PARALLEL FORCES.

1.* Show that three parallel forces cannot be in equilibrium unless one is opposite to the other two. Q. XV.

2.* Show that the equilibrant of two parallel forces must have the same line of action as their resultant. Q. XI.

3.* Show that one of three parallel forces in equilibrium must be equal in magnitude to the resultant of the other two, and hence equal to the algebraic sum of the other two. (Axiom).

4.* Show that the equilibrant of two forces in the same direction must lie between them, and in the same plane with them. Q.

5.† Show that the line of action of the equilibrant of two forces in the same direction must divide the distance between their lines of action into parts inversely proportional to the magnitudes of the two forces, in order that equal and opposite couples may be produced, and that this condition is consistent with those above.

6. Compare the moment of two parallel forces about any point in their plane with the moment of their equilibrant about this point. Q.

7. Where is the equilibrant of two parallel forces in opposite directions? and what becomes of it as the forces become more and more nearly equal? D. 26.

8.* State the (three) conditions of equilibrium of three parallel forces. D. 19.

XVII.

THE LEVER.

1.* Describe an ordinary (straight) lever, stating what is meant by the "arms" of the lever, the "fulcrum," (F) "power," (P) and "weight," (W). D. 56, 57.

2.* Distinguish three classes of levers, stating which of the three forces is in the middle in each case. D. 56, 57.

3.* In which class of levers is the weight always greater than the power? always less? sometimes greater and sometimes less?

4.* Which force in each class of levers is equal to the sum of the other two?

5.* State the law of levers. Q. XVI.

6.† Show that each of the three forces in equilibrium in the lever is proportional to the distance between the lines of action of the other two.

7.‡ Describe one or more experiments with the arithmetical lever, and state what points each illustrates. D. 25.

8.* What is meant by a bent lever? D. 57.

9. Distinguish the "arms" of a bent lever from the "arms" of the couples which are in equilibrium. D. 57.

10* When are the forces acting on a bent lever in equilibrium? Q. XVI.

11.‡ Describe one or more experiments (with E. H. HALL'S apparatus) illustrating the equality of moments in the bent lever.

XVIII.

COMPOSITION AND EQUILIBRIUM OF COUPLES IN PARALLEL PLANES.

1.† Describe the condition of the rod of a torsion apparatus during torsion.

2.† Show that a rod subject to torsion can offset the action of a couple.

3. When a rod is twisted by a couple acting at one end of it, what is the nature of its reaction against the agent through which the couple is produced? (Axiom).

4. Show (by considerations of symmetry) that a uniform free rod, subject to torsion, must react equally at both ends against agents producing the torsion. (Axiom).

5.† What is meant by a "shaft" or "axle," and when is it in equilibrium?

6.† Show that couples, like forces, exist under four aspects, and obey the same laws of action and reaction.

7.† Prove that a couple is transmitted without loss at right-angles to its plane, from one section of a body to another, and hence from one end of the body to the other.

8. What is meant by the transmissibility of couples along their axes? Prob.

9.† Show that the plane or axis of a couple has no definite position in space, but is determined only by parallelism to a given plane or axis. Prob.

10.† Show that the resultant of any number of couples with parallel planes is a single couple, with plane parallel to those of the components, and with a moment equal to the algebraic sum of the moments of the components. D. 27, Q. XIII. and XVIII.

11.‡ Describe one or more experiments (due to E. H. HALL) illustrating the conditions of equilibrium between couples in parallel planes.

12.† Show that a couple is completely specified when its moment and general direction of rotation are known. Prob.

XIX.

COMPOSITION AND RESOLUTION OF COUPLES IN NON-PARALLEL PLANES.

1.† Find the locus of all antipodal points in a given spherical surface at which tangential forces can be applied so as to produce a couple eqnivalent to a given couple.

2.† Find two antipodal points in a given spherical surface where tangential forces can be applied so as to produce two couples equivalent to any two given couples in non-parallel planes.

3.† Show that the parallelogram of forces can be applied to the composition of couples in non-parallel planes.

4.† Prove that the resultant of two couples in non-parallel planes is a single couple in some intermediate plane.

5. Apply the Pythagorean proposition to the relation between the moments of two component couples in planes at right-angles, and the moment of their resultant. Prob.

6.† Show that a couple can be resolved into components, the first parallel to any plane, and the second making a right-angle (or any other angle) with the first.

7. Find the trigonometric relation between a couple and its (rectangular) component in any plane, making the angle A with the plane of the couple. Prob.

8.† Find the component of a couple in any plane whose normal makes an angle, A, with the axis of the couple. Prob.

9.† What is meant by the moment of a force about a given axis? and what distinction is made between positive and negative moments?

10.† Show that the algebraic sum of the moments of two equal and opposite forces about any axis is equal to the component of the couple in a plane at right-angles to this axis.

11.† Show that, in a state of equilibrium, the algebraic sum of the components of all the forces along any axis, and also the algebraic sum of their moments about this axis must be zero.

XX.

WRENCHES.

1. Show that every force acting upon a body (whether part of a couple or not) can be resolved into a force with line of action passing through any given point, P, and a couple. D. 28, 29; Q. XIV. 1.

2. What is the nature of the resultant in the last question, of all the forces passing through a single point, P? Of all the couples? D. 29; Q. VII., XVIII., XIX.

3.† Show that all possible forces acting on a body can be resolved and recompounded into a single force with line of action passing through a given point and a single couple. D. 29; Q. 2.

4.† Show that the couple in the last question can be resolved into two components, one at right-angles to the force, the other parallel to it, and state the result of combining one of these components with the force. D. 29, Q. XIX. 6, XIV. 4.

5.† Show that all possible forces acting on a body (whether parts of couples or not), are equivalent to a single force with definite line of application, and a single couple at right-angles with this force. D. 29, Q.

6. What name is given to a force combined with a couple at right-angles to it? D. 29, 30.

7. Define the word "wrench" as used in (theoretical) mechanics. D. 29, 30.

8. Show that all possible combinations of forces are reducible to a wrench. D. 29, 30; Q.

9.† Distinguish right and left-handed wrenches, according to the direction of rotation, as looked at in the direction of the force.

10.† Show that the reaction against a right or left-handed wrench, being equal and opposite in respect to both force and couple, is a wrench of the same kind, as concerns the relation between linear and rotatory displacement.

11.† Distinguish wrenches farther into two classes, according to whether extension or compression is produced.

12.† Discuss the wrenches exerted in certain familiar mechanical processes (such as driving a screw).

13.† Show that extension in one part of an elastic system implies compression in some other part.

14. In what respect are the wrenches exerted by two different parts of an elastic system on each other similar, and in what respect dissimilar? Q.

15.† Discuss the longitudinal and torsional effects of mutual wrenches in the ordinary spring curtain-roller.

16. State the law of action and reaction as applied to wrenches. D. 30.

XXI.

ELASTICITY OF SOLID BODIES.

1.† Name three effects of a wrench upon an elastic body.

2.* Distinguish stretching, bending, twisting, and compression.

3. What is meant by elasticity? by limits of (perfect) elasticity? by a set? or permanent strain? D. 126.

4. Define a stress, a strain, and a coefficient or modulus of elasticity. D. 128.

5.‡ Describe one or more experiments illustrating effects of longitudinal forces upon wires or rods.

6.† State the law connecting the stretching of a rod with the force applied, with the length of the rod, and with its area of cross-section.

7. What is meant by YOUNG'S modulus of elasticity? D. 128.

8.† Give some idea of the relative magnitudes of the forces necessary to produce a given stretch in rods of different materials, but of the same dimensions.

9.† State the usual effect of stretching on the diameter of a rod, and what is meant by "POISSON'S ratio."

10.† What connection (if any) exists between the relative magnitudes of the forces necessary to produce a given amount of stretching, and the relative magnitudes of those required to produce a given amount of bending in bodies of given dimensions?

11.‡ Describe one or more experiments relating to the laws of bending.

12.† State the laws connecting the bending of a beam with the load, and with the length, breadth, and thickness of a beam.

13.‡ Describe one or more experiments relating to the laws of torsion.

14.† State the laws connecting the twisting of a rod with its length, with its breadth, and with the magnitude of the couple applied.

15.† Give some idea of the relative magnitudes of the couples necessary to produce a given amount of twisting in bodies of the same dimensions, but different materials.

16.† What is meant by a modulus or coefficient of torsion?

17. What is meant by elasticity of volume? by resistance to compression? by compressibility? D. 129.

18.† Explain how the compressibility of solids (as well as liquids) can be demonstrated by an (OERSTED'S) piezometer.

19.† What connection (if any) exists between YOUNG'S modulus, the modulus of torsion, and the resistance to compression for a given material?

20. Show that HOOKE'S law applies to cases of stretching, bending, twisting, and compression.

XXII.

CENTRE OF GRAVITY.

1.† When is a force applied to a rigid body said to have a definite point of application? (D. 34).

2.† What is meant by a centre of force? by the centre of two or more forces?

3.† Distinguish between a true centre of force, as for instance an ideal atom, and a virtual centre of force, as for instance the centre of Saturn's rings.

4. Show that the centre of two parallel forces (not equal and opposite) having definite points of application lies in the line joining these points of application. D. 34.

5. Where is the point of application of the resultant of two parallel forces (not equal and opposite)? D. 34.

6. Show that if any number of parallel forces (whose algebraic sum is not zero) have definite points of application, they give rise to a resultant with a definite centre or point of application. D. 34.

7. Show that the forces which the earth's gravity exerts upon the molecules of a small body at the earth's surface, having definite points of application, and being (practically) parallel, must have a definite centre or point of application. D. 33, 34.

8. What name is given to the centre or point of application of the (parallel) forces which gravity exerts upon the different elementary particles of a body? D. 34.

9. Define the term "centre of gravity," and state whether it is applicable to solids only, or also to liquids and gases. D. 34, 35.

10.† Show that if masses are measured by the forces which gravity exerts upon them, the centre of gravity coincides (by definition) with the "centre of mass."

11.† Would the statement in the last question hold if the masses were not measured by the forces which gravity exerts upon them? or if the forces in question were not parallel?

12. Under what circumstances does the centre of (the forces due to) attraction coincide with the centre of mass? Q.

13. Under what conditions does the resultant of two or more forces have a definite centre or point of application? Q.

14. Where is the centre of gravity of two equal masses? of two unequal masses? D. 34.

15.† Show that the centre of gravity of two, three, or four equal masses is at the geometrical centre of this line, triangle, or pyramid which they define. (D. 37-39).

16.† Show that three or more unequal masses must have a fixed centre of gravity, independent of the order in which they are considered. (D. 37).

17. Show (by geometry) that in a system of mass, M, consisting of two masses, m_1 and m_2, at the heights, h_1 and h_2, the height, H, of the centre of the gravity is such that $MH = m_1 h_1 + m_2 h_2$. D. 22, 45.

18. Extend the principle of the last question to the case of any number of masses. D. 23, 45.

19. Show that the principle of the last two questions applies not only to the heights, H, h_1, h_2, etc., of the centre of gravity and separate masses composing a system, but also to their distances, D, d_1, d_2, etc., from any plane. D. 22, 23.

XXIII.

CENTRE OF GRAVITY OF GEOMETRICAL FIGURES.

1. What assumption (as to the distribution of weight) is made in calculating the position of the centre of gravity of bodies approximating to geometrical figures? D. 35.

2. What is meant by the centre of gravity of a geometrical solid? surface? or line? D. 35.

3.* Show that the centre of gravity of a uniform thin rod (or line) is at its centre, and that it will balance about any axis passing through this centre. D. 36.

4.† Show that the centre of gravity of two equal triangles or pyramids, symmetrically situated with respect to their common apex, is at this apex.

5. Prove that if a figure can be cut up into strips, slices, pairs of triangles, pairs of pyramids, etc., each having its centre of gravity at or in a given point or axis, the centre of gravity of the whole figure must be at or in this point or axis. Prob.

6. Show that if any figure is symmetrical with respect to a centre (so that it can be cut up into equal and opposite pairs of pyramids, with common apex at this centre) its centre of gravity must lie at this centre. Prob. D. 36. Q. XVIII.

7. Show that if any figure is symmetrical with respect to an axis, (so that it can be cut up into equal and opposite pairs of triangles with common apex on this axis) its centre of gravity must lie on this axis. Prob. (Q. XXIII.)

8. Show that if any figure is symmetrical with respect to a plane (so that it can be cut up into uniform thin strips, each with its centre of gravity in this plane), the centre of gravity of the figure must lie in this plane. Prob. (Q. XXIII.)

9. Where is the centre of gravity of a figure symmetrical with respect to two axes? an axis and a plane? two planes? three planes? Prob.

10. Find the centre of gravity of a circle, square, ellipse, parallelogram, cube, block, parallelopiped, prism, cylinder, sphere, ellipsoid, etc. Prob. D. 36.

11. Show (by cutting up a triangle into strips parallel to the base, and considering the centre of gravity of each strip) that the centre of gravity of a triangle must lie in its medial line. D. 37.

12. Show that the centre of gravity of a triangle must lie at the point of intersection of its medial lines, and find (by geometry) the relative altitudes of the apex and centre of gravity. D. 37, Q. 11.

13. Show (by cutting up a pyramid into sections parallel to the base) that if a line be drawn from the apex to the centre of gravity of the base (so as to pass through the centre of gravity of each section), this line will contain the centre of gravity of the pyramid. D. 38.

14. Show that the centre of gravity of a pyramid must lie at the point of intersection of two or more lines drawn as in the last question, and find (by geometry) the relative altitudes of the centre of gravity and apex of a triangular (or any other) pyramid. D. 38.

15. Find the centre of gravity of a cone by the same method as in the last question. D. 38.

XXIV.

CENTRE OF GRAVITY OF SUSPENDED BODIES.

1.† Find the moment of the force exerted by gravity on a body of weight, W, about a horizontal axis in a vertical plane at the distance, D, from the centre of gravity. (D. 58).

2.† A body of weight, W, and centre of gravity at the horizontal distance, D, from a fulcrum (or axis) is balanced by a force, P, acting on a horizontal arm, A. Find the equal and opposite moments. (D. 58).

3. In the last question, express each of the four quantities, W, D, P, and A, in terms of the other three. Prob. Q. 3.

4.‡ How can you find the weight of a body by balancing it on an axis by means of a known weight? Q.

5.‡ How can you locate the centre of gravity of a body of known weight when balanced on an axis with another body of known weight? Q.

6.‡ Show how the weight of any object, great or small, can be found by a graduated lever of known weight. Q.

7.‡ Show how the position of a bullet of known weight in a gun-barrel of known weight can be found from the displacement of the centre of gravity. Q.

8.*‡ Describe one or more experiments with levers showing that their weight acts always as if concentrated at their centre of gravity.

9.* Explain and describe one or more experiments illustrating the behavior of bodies suspended at their centre of gravity.

10. Show that a body is in equilibrium if suspended at any point in a vertical line passing through the centre of gravity. D. 41.

11.* What is the result of suspending a body at a point not contained in the vertical line passing through the centre of gravity?

12. State the condition of equilibrium in a body suspended at a point. D. 41.

13.* Describe the experimental location of the centre of gravity of a body by the method of suspension. D. 43, 44.

14.‡ Describe and explain one or more experiments in which a body is suspended upon a horizontal axis in a vertical plane containining the centre of gravity, and state how the centre of gravity may be located by such experiments.

15.* What is the result of suspending a body upon a horizontal axis not containing the centre of gravity?

16. What is the result of suspending a body upon an oblique axis containing the centre of gravity? not containing it? Prob.

17.* Describe the condition of a body suspended about a vertical axis.

18. State the conditions of equilibrium of a body suspended upon an axis, in terms of the position of the centre of gravity with respect to this axis. D. 41.

19. Show that in all the cases above, where a body is not in equilibrium, the action of gravity is such as to cause the centre of gravity to descend. D. 16.

20. Show that a heavy body is in equilibrium when, and only when, the nature of its restraints is such as to prevent the centre of gravity from descending. Prob.

21.‡ Explain the action of a double-pointed cone in rolling up two inclined, but diverging rails.

22. Explain the action of a ball in rolling into the deepest portion of a hollow. D. 46.

23. Show that, in general, the centre of gravity tends to descend. D. 46.

XXV.

STABILITY, AND ITS RELATIONS TO CENTRE OF GRAVITY.

1. Show that a body, in which two points are fixed, is equivalent to one suspended upon an axis passing through these points. Prob.

2. How many points in a body must be fixed to prevent movement of any kind? Prob.

3.† Three points in the same horizontal plane are fixed. Find the direction of the force on each, according to the position of the centre of gravity.

4. Describe the forces by which a tripod is usually held in place, stating the direction of these forces, and whether they vary uniformly or "per saltum" under displacement. D. 40, 52.

5. State the conditions under which a body may be fixed by the upward reaction of three forces. Q.

6.† What name is given to the area of a horizontal section included between the forces in the last question?

7.* Define, in general, the "area of support" of a body. Q.

8.† Show that a body is stable if its centre of gravity lies above its area of support. (D. 40).

9. What is meant by the limit of stability in a body supported at three or more points? D. 54.

10. Show that a body, displaced within its limits of stability, tends to return to its original position. Prob.

11. When is a body said to be "practically stable?" D. 54.

12. What, in general, is meant by stability? D. 42.

13. Distinguish stable, unstable, and neutral equilibrium, according to the tendency of a body when displaced to return to its original position of equilibrium. D. 42.

14. When is a heavy body, suspended by a point or by an axis, in stable equilibrium? in unstable equilibrium? in neutral equilibrium? State the position of the centre of gravity relatively to the point or axis of suspension in each case. D. 41, 42.

15. Explain the toy called "the balancer." D. 53.

16. Show that, in a condition of stability, the height of the centre of gravity is at a minimum, in a condition of instability at a maximum. D. 46.

17. State the conditions which determine whether equilibrium exists, and whether it is stable or unstable, in terms of the path of the centre of gravity consequent upon a given displacement of the body. D. 46.

18. Find the state of equilibrium in a sphere or cylinder rolling on a flat, on a concave, and on a convex surface. Prob. (D. 46).

19. Describe and explain the action of a toy known as "the tumbler," or any other similar device. D. 53.

XXVI.

SENSITIVENESS OF A BALANCE AS RELATED TO CENTRE OF GRAVITY.

1. Name the essential parts of a balance. D. 70.

2.‡ Describe the beam of an ordinary balance, the knife-edges and their bearings. D. 75.

3.‡ Describe the pointer or index of a balance, the scale-pans, and the means for arresting the loads, or lifting them from the knife-edges.

4. Explain the importance of preserving the sharpness of the knife-edges, and the ordinary precautions taken to this end. (D. 75).

5. Where is the centre of gravity of a balance-beam, and how is the position of the centre of gravity adjusted? D. 73.

6. Show that the weights act as if concentrated at the knife-edges. Prob. Q. XXII. 1.

7. Show that if the three knife-edges be in the same straight line, the centre of gravity is not disturbed by loading the scale-pans so as to produce equilibrium. Prob. Q. XXII. 5.

8. Show that in a straight-arm balance, we have for the angle, a, of deflection due to excess of weight, p, on arm of length, l, of the beam of weight, w, with its centre of gravity at a distance, d, from the axis,

$$\tan a = pl \div wd.$$ D. 73.

9.† What additional terms must be considered if the three knife-edges are not in the same straight line? D. 74.

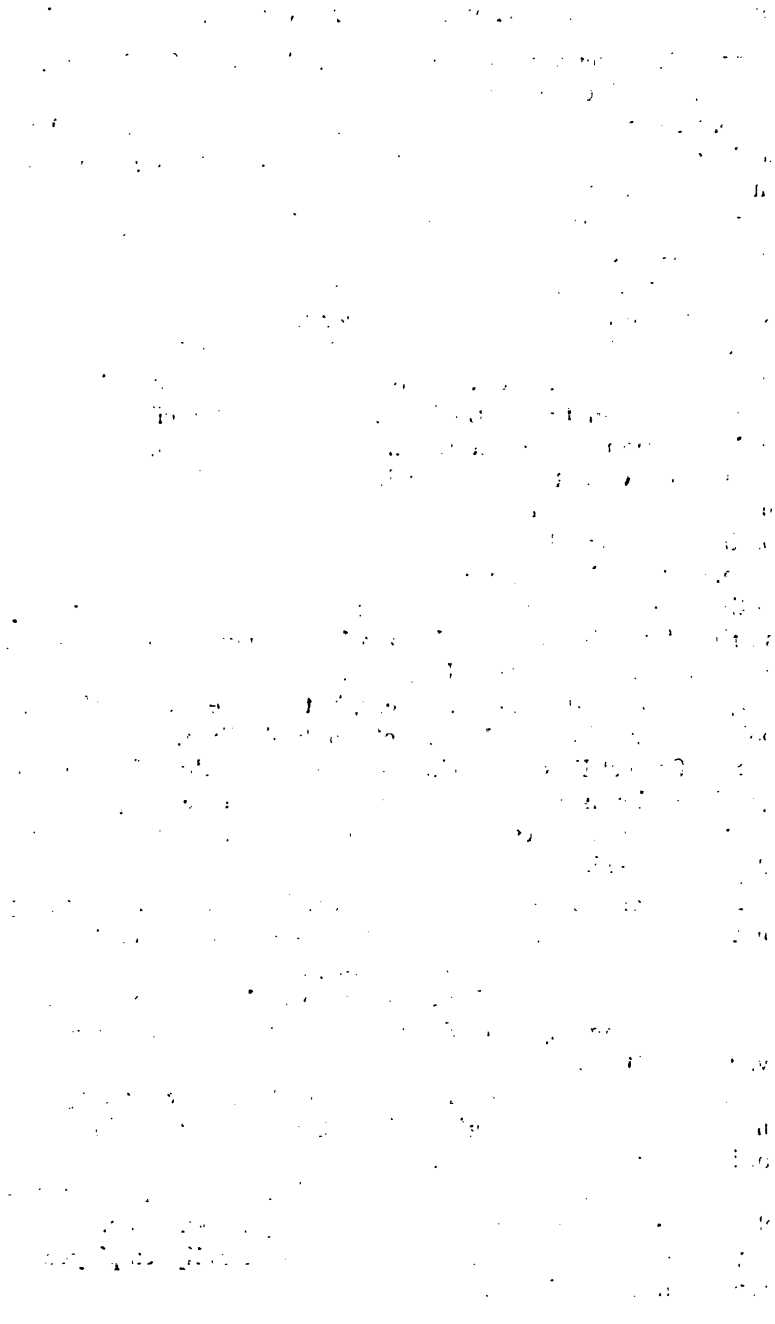
10. Show that if the outer knife-edge be above the middle knife-edge, the equilibrium of the balance may become unstable from loading. D. 74.

11. Show that if the outer knife-edges be below the central knife-edge, the equilibrium of the balance will become more stable on loading. Prob. D. 74.

12. Distinguish three types of balance, according to alignment of the knife-edges. Q.

13. Show that a balance beam may belong, successively, to the three several types named in the last question, through bending under an increasing load. Prob.

14.† What is meant by the sensitiveness of a balance?



15. State certain conveniences in the use of a balance of known sensitiveness. D. 74.

16.† Describe the method of weighing under a constant load, and state some of the advantages and disadvantages of this method. D. 74.

17.‡ How is the sensitiveness of a balance under a given load ordinarily determined?

18.† Explain the use and construction of a table showing the sensitiveness of a balance under different loads.

19.‡ Describe the use of a "rider," and show that in weighing with a rider, the sensitiveness of a balance need not be known.

20.‡ Explain the method of weighing by "oscillations" (or by "vibrations"), and state some of its advantages.

21.† Show that friction, within certain limits, does not necessarily affect the sensitiveness of a balance, if the method of oscillations is employed.

22.† State what advantages are to be gained by using a balance with rapid oscillations, to what extent sensitiveness should be sacrificed to this end, and to what extent sensitiveness is consistent with rapidity. D. 71, 74.

23.† Show that it is convenient, but not necessary, that the pointer should indicate how much the loads differ.

24. Correct DESCHANEL'S statement (§73) that the centre of gravity and axis of a balance "must not coincide." Q.

25. What qualities are sought for in a balance? D. 71, 73. Q. XXVI. 1-26.

26.* Describe the ordinary "steelyard," and show that equality of the arms of balance is not necessary in order that the true weight of a body may be found. D. 76.

27. Describe (BORDA'S method of) weighing by substitution, (or double weighing, according to DESCHANEL and other French writers). D. 72.

28.‡ Describe (what is meant by most English writers by) the method of "double weighing," (or GAUSS'S method, involving an interchange of the loads).

29.† Show that the method of double weighing (by interchange) is twice as accurate as weighing by substitution.

30.‡ Describe, in detail, the processes actually employed in very accurate weighings.

XXVII.

WORK, AND ITS RELATIONS TO CENTRE OF GRAVITY.

1.* What name is given to the product of a force (when constant in magnitude and in direction) and the displacement of its point of application (in the same direction)?

2.* Define work, and name some of the units in which it is measured.

3.* Define the foot-pound and kilogram-metre.

4.† Define the foot-poundal, and erg (or dyne-centimetre).

5.* Find the work, W, necessary to raise a weight, w, through the vertical distance, d. D. 45, 47.

6.* Distinguish between the work done by a force upon a weight or against gravity, and that done by gravity or by the weight against the force. D. 47.

7. How is work measured when the directions of the force and displacement are not the same? D. 45, 48.

8. The point of application, A, of a force, AB, moves to C. What kind of work is done by the force if BAC is acute? if BAC is obtuse? if BAC is a right-angle? D. 48.

9. Find the work done by a force, AB, in producing the displacement, AC, in terms of AB, AC, and a function of the angle, BAC. D. 48.

10. Show that the work done by a force in producing a given displacement may be measured (1) by the product of the displacement and the component of the force in the direction of the displacement, or (2) by the product of the force and the component of the displacement in the direction of the force. Prob. Q.

11. Show that the work necessary to move a weight in any direction is the product of the weight and the vertical component of the displacement. D. 48.

12. A body of weight, W, remains fixed, while another body, of weight, w, moves through the distance, D. Find (by geometry) the displacement, d, of the centre of gravity of the two weights. Prob.

13. Compare, in the last question, the components of the two displacements in the vertical (or any other) direction. Prob.

14.† Show that the product of a weight, forming part of a system, by its vertical displacement is equal to the product of the weight of the whole system by the vertical displacement of its centre of gravity. Q.

15.† What is meant by the work done upon the centre of gravity of a system?

16.† Show that the algebraic sum of the quantities of work done upon the separate weights of a system (by considering these one by one) is equal to the work done upon the centre of gravity of the system. Prob.

17. State the "principle of work" as applied to the centre of gravity of a system of weights. D. 45.

18. Explain how the calculation of work done upon a body can be simplified by the principle of the last question. D. 45.

19. Find the work, W, necessary to pile a given weight, w, of fragments into a rectangular, into a triangular, or into a pyramidal heap of height, h, above the (mean) level of the fragments. D. 45.

20. Modify the last question so as to apply to the case of filling cisterns of different shapes with liquids, or exhausting wells of different depths and shapes. Prob.

XXVIII.

WORK, AS A CRITERION OF STABILITY.

1. Find the work, W, necessary to turn a block of length, l, breadth, b, thickness, t, and weight, w, from its position of maximum stability into its position of medium or minimum stability. Prob. D. 45.

2. Modify the last question so as to apply to an ellipsoid. Prob.

3. A barrel of weight, w, rests upon a floor in stable equilibrium, because its centre of gravity is at a distance, d, below the axis: find the work, W, necessary to start the barrel rolling. Prob. Q.

4.* State some of the most important properties of the centre of gravity. Q. XXII.-XXVII.

5. Show that work must be done upon a body to displace it from a position of stable equilibrium. D. 50.

6. Show that work is done by a body when it is displaced from a position of unstable equilibrium. D. 50.

7. Show that no work is done upon or by a body when it is displaced from a position of neutral equilibrium. D. 50.

8. State the criterion of the stability of equilibrium in terms of the total work done upon or by a body when displaced from its position of equilibrium. D. 50.

9.† What condition of equilibrium is assumed to exist in an ideal lever?

10.† State, in general, what kind of equilibrium exists in various ideal machines or "mechanical powers."

XXIX.

PRINCIPLE OF WORK APPLIED TO MECHANICAL POWERS.

1.*†Show, by geometry, that the work spent by a force acting upon an ideal lever is equal to the work utilized in the weight raised.

2.* State the "principle of work" (or "virtual velocities") as applied to the lever. D. 49.

3.* What assumptions (in regard to loss of work by friction, etc.) are made in the investigation of ideal machines? (D. 49).

4. What distinction is made between the force known as the "power" and the "weight" in various machines? D. 59.

5. What is meant by mechanical advantage? D. 59.

6. Name some of the most important "mechanical powers." D. 55.

7. Show that the wheel and axle may be regarded as an endless lever. D. 60.

8. Find (by the principle of work) the relation between the power, weight, and radii of a wheel and axle. Prob.

9. How would the results obtainable with a wheel and axle be modified by the thickness of the ropes, if these were perfectly flexible? D. 60.

10.† In what way would the stiffness of the ropes of a wheel and axle modify the result if the ropes were perfectly elastic, so that no work need be spent in bending them?

11. Show that a pulley may be regarded as an endless lever. D. 61.

12.† What assumption as to the tension of the cords passing round one or more pulley-wheels is made in calculating the mechanical advantage of ideal pulleys?

13.* What mechanical advantage is gained by a single fixed pulley? D. 61.

14.† What allowance must be made for the weight of a movable pulley? for the weight of the cords?

15.‡ How is the influence of the weight of pulleys and cords eliminated in experimental demonstrations?

16.* State the mechanical advantage of a single movable pulley, to which the weight is attached, assuming the cords parallel. D. 61.

17.* State in general the mechanical advantage of a pulley moved by x cords with uniform tension in the same direction. Prob. D. 62.

18.* Show that the principle of work applies to the case of a pulley with x cords, as in the last question. Prob. D. 61.

19. Find the mechanical advantage of a series of x single pulleys, each attached to the power cord of the next. Prob. D. 63.

20.† What is meant by an ideal smooth surface or plane? and what limitations exist in the direction of the force which such a surface is capable of exerting upon a body?

21‡ Describe one or more experiments with inclined planes approximating to the ideal conditions.

22. Explain the resolution of forces in a body resting on a perfectly smooth inclined plane. D. 64.

23. A body of weight, w, rests on an inclined plane of length, AC, base, AB, and height, BC: find the force by which it is held in place, (1) if this force is tangential, (2) if the force is horizontal. Prob. Q.

24. Show that the principle of work applies to the forces known as the "power" and the "weight" in an inclined plane. D. 65, 66.

25. Show that a wedge may be regarded as a special case of inclined plane. D. 67.

26. Find the mechanical advantage of an ideally smooth wedge of length, l, and thickness, t. Prob. Q.

27.* Show that a screw can be treated as a special case of inclined plane. D. 68.

28.* Find the mechanical advantage of a screw of circumference, c, and distance, d, between threads measured parallel to the axis of the screw, if the force is applied at the circumference, at right-angles to the axis. Prob. Q.

29.* By what means is the mechanical advantage of a screw greatly increased in ordinary screw presses? D. 69.

30.* Find the mechanical advantage of a screw press with arms of length, l, and threads, at the distance, d. D. 69.

31.*† Estimate, approximately, the force which can be brought to bear in an ordinary screw press, neglecting friction.

32.* Show that the principle of work applies to the screw press.

33. Show that all the mechanical powers are reducible to two types (the lever and the inclined plane).

34.* State, in general, the application of the principle of work to mechanical powers. D. 49.

35.* What is meant by the statement that "what is gained in power is lost in speed?" Prob. Q.

36.* An ideal machine is actuated by a force, F, acting through a distance, D, and produces a force, f, acting through a distance, d; express each of the four quantities, F, f, D, and d, in terms of the other three.

37.* In the last question, state what must be, and what need not be known about the construction of the machine, in order that the principle of work may be applied. Q.

XXX.

CONSERVATION OF WORK.

1.† A weight, w, is moved through the distances, AB, BC, . . . YZ, all lying in the same vertical line. Show that the work done is the same ($w \times AZ$), whatever may be the position of the intermediate points, B, C, etc.

2. Prove that if a weight, w, is moved along any broken path, $A''\ B''\ C'\ .\ .\ .\ Z''$, the work done is the same as along the projection of this path, $A'B'C'\ .\ .\ .\ Z'$, on a vertical line, and hence, equal to $w \times A'Z'$. Prob.

3. Show that in returning from Z'' to A'', the weight gives out the same amount of work that it received between A'' and Z''. Prob. D. 123.

4. Show that work done against constant forces, like those exerted by gravity, depends only upon the initial and final positions of a body, and is independent of the path of the body. Q. (D. 123).

5. Show that when a body returns by any "closed path" to its original position, the total work done upon it, or by it, is zero. Q. (D. 123).

6.† Discuss, from the point of view of the last question, the possibility of various proposed forms of "perpetual motion." (D. 49).

7. State the relation between the work received by a body in one part of a closed path, and that given out by it in the remainder of its path. Q.

8.*†What is meant by the "conservation of work" in mechanics?

XXXI.

LOSS OF WORK BY FRICTION.

1.* What element, entering into the working of all practical machines, causes a departure from ideal conditions? D. 49, 125, 131.

2.* Define (kinetical) friction (D. 131), and state the peculiarity of sign in the work to which it gives rise.

3.‡ Describe and explain one or more experiments showing a great discrepancy between the force required to start a body sliding (no matter how slowly) over a surface, and that required to maintain the motion. (D. 131, 132).

4.‡ State the results of one or more experiments showing whether the force required to drag a body over a surface is or is not affected by the velocity. (D. 131).

5.† Why is it necessary, in measuring forces due to friction, that bodies should be moved with uniform velocity?

6.‡ State the results of one or more experiments showing the relation between the force required to drag a body over a surface, and the (normal) force urging the body and the surface together. D. 131.

7.‡ What is the result of varying the area of rubbing surfaces, without varying either their nature or the force urging them together?

8. What is meant by a "coefficient of friction?" D. 131, 132.

9.‡ Describe one or more experiments in which the coefficient of friction between two horizontal surfaces is determined.

10. A body of weight, W, requires a force, w, to drag it with uniform velocity, along a horizontal surface; find the coefficient of friction between the body and the surface. Prob. Q.

11. What is meant by the "limiting angle of friction" for two surfaces? D. 132.

12.‡ Explain the experimental determination of coefficents of friction by means of an inclined plane. D. 133.

13. A body slides with uniform velocity down an inclined plane with base, AB, and height, BC: find the coefficient of friction. D. 133.

14.† Give some idea of the magnitude of coefficients of friction between wooden or metallic surfaces, and the effect of grease or oil upon these coefficients.

15.† Show that the mechanical advantage of a wedge or screw, no matter how fine the pitch, cannot exceed the reciprocal of the coefficient of friction.

16.† Find a relation between the weight, W, of a truck, the diameters, D, and d, of the wheel and axle, the coefficient of friction, f, of the (loose) bearing upon the axle, and the force, F, required to pull the truck. Illustrate by a numerical example.

17.† Find the difference between the forces, F' and F'', transmitted by parallel cords to and from a pulley of diameter, D, with axle of diameter, d, and coefficient of friction, f, on its loose bearing, (calling the force borne by the pulley $F' + F''$).

18.† Trace out the effect in a double block (with four cords) of a loss of 10 per cent., 20 per cent., etc., in the tension of each cord passing round each wheel, on the force required to lift a given weight by the block, remembering that the weight raised is given by the sum of the tensions on the cords.

19.† Find, conversely, the weight on the block necessary to overcome a given force at one end of the cord.

20.† Explain the enormous loss of work in long trains of clock-work, and the surprising effects of oil upon these.

XXXII.

EFFICIENCY.

1.‡ Describe one or more experiments showing that the work spent upon the cord of a tackle in raising a weight is greater than that utilized through the pull upon this cord exerted by the descending weight.

2.† What name is given to the ratio of the work spent to the work utilized in a given case?

3. Define "efficiency," as used in mechanics. Q. 2.

4.† Distinguish between the efficiency of a tackle as a machine for raising weights, its efficiency as a machine for utilizing work done by the descent of a weight, and its efficiency as a machine for storing useful work.

5.† State a certain necessary relation between the three efficiencies in the last question.

6. A man slides a box up into a wagon along a board inclined at the limiting angle of friction: (Q. XXXI.) find the efficiency of his combination. Prob.

7. Show that the efficiency of a screw, irreversible through friction, cannot exceed 50 per cent. Prob.

8.† Show, from a point of view of efficiency, the disadvantage of a screw with too fine a thread (or of a differential screw).

XXXIII.

POWER.

1.‡ Describe one or more experiments with an ergometer (or friction-brake), showing how it is possible to measure the work spent by a given agent in a given time.

2.‡ Describe a "transmission dynamometer," and its uses.

3.† What name is given to the quotient of work by time? to the product of force and velocity?

4.† Distinguish power, in its technical sense, from power as a name for one of the forces in a machine.

5.† Define power in two different ways, and show that these definitions are identical. Q. 3.

6.† Define "horse-power" (English or French), the erg per second, and the "watt."

7.† Show that the horse-power varies slightly in different latitudes, but that the erg and the watt are constant.

8.† Find the horse-power of a locomotive with two cylinders 100 square inches in section, and double two-foot stroke, making 125 revolutions per minute under a mean pressure of 33 lbs. of steam per square inch, in both the forward and backward stroke, making no allowance for friction.

9.† Find the power, P, spent upon a water-motor with piston of area, a (sq. cm.), making n double strokes of length, l, (cm.) in every second, under a pressure, p (dynes per sq. cm.), and state in what units the result is expressed.

10.† Show that the power, P, spent upon a motor (by an incompressible liquid) is equal to the product of the pressure, p, per unit of area, and current, c, in units of volume per unit of time.

11.† Show that (as a consequence of the principle of the last question), if pressure is transmitted by an incompressible fluid without loss, power must also be transmitted without loss.

XXXIV.

SOLIDS AND FLUIDS, DISTINGUISHED.

1.‡ Describe an experiment (with OERSTED'S piezometer), showing that liquids are compressible. D. 130.

2.* Distinguish fluids from solids (in respect to their relative resistance to, and limits of recovery from, changes of form or shape unaccompanied by changes of bulk or volume). (D. 129).

3.† Distinguish fluids from solids in respect to their rates of yielding to tangential or transverse forces, and state whether this distinction is one of kind or of degree.

4.† What name is given to that property in solids which is connected with their slow yielding under transverse stresses?

5.† When is a solid, and when is a fluid said to be especially viscous? (D. 135).

6.† Show that viscosity is used in two opposite senses in its applications to solids and fluids.

7.† Distinguish frictional forces within the body of a fluid (whether due to viscosity or not) from forces due to the rubbing of two solid surfaces, in respect to their dependence upon (1) the compression, (2) the area, and (3) the relative velocity of the moving parts.

8.* State some of the characteristic distinctions between solids and fluids. Q.

XXXV.

LIQUIDS AND GASES DISTINGUISHED.

1.‡ Describe an experiment (with a gas-bag and air-pump) illustrating the indefinite expansibility of a gas. D. 194.

2.* Distinguish fluids into two classes, according to their tendency toward uniform distribution throughout any space within which they are confined. D. 194.

3.* How do liquids compare, as a class, with gases, in respect to density?

4.* How do liquids compare, as a class, with gases, in respect to compressibility?

5.† What is meant by the "free surface" of a fluid, and what kind of fluids alone present such surfaces under ordinary conditions?

6.‡ Describe one or more experiments (*e.g.*, with floating needles), showing that the surfaces of liquids resist deformation to a slight extent. D. 159.

7.‡ Describe one or more experiments (with camphor and water, oil films on water, and the effects of local heat or alcohol) showing that slight tangential forces are exerted by the surfaces of liquids. D. 192.

8.‡ Describe one or more experiments (with PLATEAU'S films) showing that the surface of a film is a minimum consistent with its boundary. (D. 186).

9. Explain the spherical shape of rain-drops or bubbles. D. 189.

10.‡ Describe one or more experiments showing that films of liquid, when free to do so, cause their boundaries to contract.

11. State the influence of the length, the breadth, and the thickness of a film on the force with which it contracts longitudinally. D. 185.

12. What is meant by "surface tension?" D. 185.

13. How many surfaces is a (soap-bubble) film considered to possess? and how is the surface tension of such a film measured? D. 188.

14.* Describe one or more experiments illustrating adhesion between a liquid and a solid which it wets.

15.* Describe the surfaces of liquids of two different kinds, near the edges of the vessels containing them. D. 182.

16.* What is meant by a capillary tube? by capillary forces? and by capillarity in general?

17.* Describe the rise and fall of liquids caused by capillary tubes. D. 182.

18.* When will a liquid rise in a capillary tube, and when will it be depressed by it? D. 182.

19. Describe the "meniscus" (or curved surface) of a liquid accompanying (1) capillary ascensions and (2) capillary depressions. D. 182, 190.

20. Explain the rise of liquids in capillary tubes which they wet, and their depression by capillary tubes which they do not wet. D. 186.

21. State some of the conditions which influence the amount of the rise or fall of a liquid in a capillary tube. D. 183, 184.

22.† What is meant by the height of the meniscus (or sagitta)?

23. What is meant by the angle of contact between a liquid and a solid? D. 184, 185.

24. Find the height, h, of a column of liquid of density, d, sustained by a surface tension (in gravitation units) t, in a tube of radius, r, assuming that the tube is wet by a film of liquid tangent to its surface. D. 186.

25. State the law of diameters governing capillary ascensions and depressions. D. 184.

26.‡ Describe one or more experiments (*e.g.*, with inclined plates) illustrating the law of diameters.

27.† How high are liquids known to rise by capillary action in certain vegetable structures?

28.† Give reasons for supposing that a practical limit exists in the height attainable by capillary action.

29.‡ Describe an experiment with an air-pump, showing that capillary ascensions and depressions are not due to atmospheric pressure. (D. 185).

30.‡ Describe one or more experiments illustrating the tensile strength under certain specified conditions, of columns of liquid of considerable cross section.

31.* In what class of fluids, alone, are phenomena due to capillarity, cohesion, or surface tension perceptible? Q.

32.* State some of the characteristic distinctions between liquids and gases. Q.

33.‡ Describe one or more experiments illustrating effects *of* endosmose (or diffusion through a diaphragm) and endosmotic pressure. D. 193.

34. Distinguish solutions into two classes with respect to the facility with which they pass through a diaphragm. D. 193.

35. Describe the process of separating colloids and crystalloids by "dialysis." D. 193.

36. Describe one or more experiments illustrating the diffusion of gases, and the pressures to which such diffusion may give rise. D. 193, 227.

XXXVI.

FUNDAMENTAL ASSUMPTIONS IN HYDROSTATICS.

1.† What assumptions are usually made in the solution of problems in hydrostatics, with respect to viscosity, capillarity, osmosis, etc.?

2. Why does not viscosity enter into problems is hydrostatics? D. 135.

3.† State reasons for assuming that capillary forces may be neglected in the treatment of bodies of liquid of considerable size, or in the case of solids of considerable size immersed in these liquids.

4.‡ Give experimental grounds for the assumption that forces or pressures due to osmosis or to diffusion are not perceptible in the wide channels usually employed in hydrostatics.

5.† Show that, in the absence of viscosity and capillarity, normal forces and pressures are the only ones which need be taken into account. (D. 135).

6. Distinguish hydrostatics from hydrokinetics, treating both as branches of hydrodynamics. D. 134.

7. Distinguish pneumatics from hydrostatics. D. 3.

8.† To what extent are the properties of gases studied under the head of hydrostatics?

9.† State certain obvious experimental evidence of the fact that fluids, when undisturbed for a long time, fall (practically) into a state of equilibrium.

10.† What general principle would lead to the anticipation of the result stated in the last question?

11.† What hypothesis (as to the equilibrium of fluids) lies at the foundation of hydrostatics?

XXXVII.

CONDITIONS OF EQUILIBRIUM IN FLUIDS.

1.† Show (by considerations relating to the centre of gravity) that a bubble, contained in a liquid within any enclosure, seeks the highest possible point.

2. Describe the construction and use of an ordinary spirit-level, its attachment to telescopes with cross-hairs, the conditions of, and one or more processes of testing its sensitiveness, and the method of eliminating errors of adjustment. D. 180, 181.

3. State the condition of equilibrium in the free surface of a liquid. D. 140.

4. Show, by the resolution of forces, that if the free surface of a fluid is not horizontal, it is not in equilibrium. D. 140.

5.† Show, by considerations relating to the centre of gravity, that the bounding surface between any two fluids of unequal density is in equilibrium only when horizontal. (D. 145).

6.‡ Describe one or more experiments illustrating the equilibrium of bounding surfaces between different fluids. D. 145.

7. Show that the equilibrium of a fluid would not be disturbed if any portion of it should become rigid, or should be replaced by a fixed rigid body. D. 153.

8.† Show that it is possible, by imagining rigid supports substituted for certain portions of a body of fluid, to treat the remainder as if contained in a *U*-tube, or in communicating vessels of any shape, without any change of equilibrium.

9.* State the condition of equilibrium of a liquid contained in communicating vessels. D. 178.

10.*‡ Describe one or more experiments illustrating the fact that a liquid stands at the same level in communicating vessels. D. 178.

11. Explain the construction and use of a water-level. D. 179.

12.† Show (by the principle of action and reaction) that the resultant of all the forces exerted by a fluid upon the walls of its enclosure must be equal and opposite to the resultant of the forces exerted by the walls of the enclosure upon the fluid, and hence (by the fundamental principles of equilibrium) equal to the weight of the fluid. (D. 148).

13.† Show that the weight of any portion of a fluid, of whatever shape, is equal and opposite to the resultant of the forces exerted upon this portion by the body of fluid which surrounds it.

14. Show that the difference between the forces exerted upon the top and bottom of a column of fluid with vertical sides (from which the column is supposed to derive no support) must be equal to the weight of the column. D. 139.

15. Show that the resultant forces upon the two ends of a fluid prism with horizontal axis must be equal and opposite. D. 138.

16. Find by the triangle of forces, the relation between the resultant forces upon the three rectangular faces of a triangular fluid prism of negligible weight, and show (by similar triangles) that the three forces are proportional to the areas of the three faces in question. D. 137.

XXXVIII.

PRESSURE.

1.† What is meant by intensity of pressure? and in what units is it expressed? D. 136.

2.† In what sense is the word "pressure," when unqualified, used by most modern writers? and how does this differ from another sense in which it was sometimes employed by earlier writers? D. 136.

3.† Find the (intensity of) pressure, p, (expressed in gravitation units) exerted by a weight, w, upon a horizontal surface of area, a.

4. A weight, w, of fluid is contained in a tube with vertical sides, and with an area of cross-section, a. Show that if the upper surface is free from force, the weight of the fluid is borne by the bottom of the tube, alone; and find the pressure due to the weight of the fluid upon the bottom of the tube, supposing it to be horizontal. Prob. Q. XXXVII.-XXXVIII.

5. Find the weight, w, of fluid of density, d, standing at a height, h, in a tube with vertical sides and horizontal base of area, a; find also the pressure upon the bottom of the tube. Prob. Q. XXXVII.-XXXVIII.

6. Find, as in the last question, the pressure, p, at the bottom of a vertical column of fluid of density, d, and depth, h, when in equilibrium with the surrounding fluid. Prob. Q.

7. Show (by the principle of action and reaction) that the upward pressure beneath any horizontal area, a, in the body of a fluid, must be equal to the downward pressure on this area, due to the fluid above it. Prob.

8.‡ Describe one more experiments showing that the upward pressure at a given depth in a liquid is equal to the downward pressure due to a column of liquid of the same depth and density. D. 144.

9. Prove (by the conditions of equilibrium of the pressures on the faces of a small triangular prism, with axis horizontal) that the pressure upon any surface of given area at a given depth in a fluid is the same as upon a horizontal surface of the same area, and at the same depth. D. 137. Q. XXXVII. 15.

10.* Explain the statement that the pressure of a fluid is the same in all directions. D. 137.

11. Prove (by considering the conditions of equilibrium of the forces on the ends of a prism with horizontal axis) that the pressure at two points at the same level in a fluid must be the same. D. 138.

12. Prove (by considering the conditions of equilibrium of a column of fluid with vertical sides) that in descending through the vertical distance, h, in a liquid of density, d, the pressure (measured in gravitation units) increases by the amount, hd, whether the starting point is in the free surface of the liquid or not. D. 139.

13.‡ Describe one or more experiments (with communicating tubes) illustrating the equality of pressure between columns of liquid of given vertical height in tubes having different inclinations.

14. Show (by a zigzag of horizontal and vertical prisms) that the pressure at two points on the same level in communicating vessels must be the same. Prob. D. 139, 147.

15. Show (as in the last question) that the pressure of a fluid of density, d, at a depth, h, below a given surface is greater than at this surface by the amount, hd, regardless of the shape of the vessel. D. 139, 147.

16.*‡ Describe one or more experiments illustrating the fact that the force exerted on a given area by a liquid of given depth and density is independent of the shape of the vessel containing the liquid. D. 147.

17.‡ Describe one or more experiments (*e.g.*, with E. H. HALL'S pressure-gauge) illustrating the fact that the pressure

in a liquid increases with the depth, and is the same in all directions.

18. Discuss the applicability of the principles of hydrostatic pressure to the case of liquids in capillary tubes. D. 190.

19. Show that the pressure of a liquid just within its curved surface in a capillary tube must differ considerably from that just outside of it, and show that the difference is explainable by surface tension. D. 190, 191.

20. Find the sign of the pressure of a liquid raised in vacuo by a capillary tube, on the assumption that its pressure outside of this tube, is zero. D. 190.

21. Explain the attraction between two parallel plates, or between two floating bodies of which (1) both are wet, or (2) neither is wet by the liquid. D. 190.

XXXIX.

BALANCING COLUMNS.

1.*‡ Describe an experiment in which water is introduced into one branch of a *U*-tube containing some mercury. (D. 146).

2.* If the water in the last question reaches from the level, *a*, to the level, *b*, and the mercury reaches from the level, *b*, down to the bottom of the *U*-tube and up again to the level, *c*, what is the function of the mercury below *b*? and what is the relation between the pressures exerted upon this portion of the mercury by the column of water (*ab*) above it on one side, and by the column of mercury (*bc*) above it on the other side? D. 146.

3.*†Show that the depth of a *U*-tube, below the level where two liquids abut, has nothing to do with their equilibrium.

4.*† State what portions of two liquid columns, abutting in a *U*-tube, are considered as producing equal pressures.

5.† Show that the condition of equilibrium between two balancing columns is not affected by atmospheric pressure, provided that it acts upon both alike.

6.‡ Explain the use and function of compressed air in balancing liquid columns which cannot be allowed to abut.

7. Point out the liquid columns exerting equal pressures on compressed air contained in a tube shaped like a W. Prob. Q.

8.‡ Explain the method of balancing columns of liquid by means of rarefied air.

9. Point out the liquid columns exerting equal pressures in an inverted *Y*-tube. Prob. Q.

10.* Find a relation between the densities, *D* and *d*, and the vertical heights, *h* and *H*, of two balancing columns, and express each of the four quantities in terms of the other three. Prob. Q.

11. Describe three methods of balancing columns, and explain how the relative density of two liquids can be found by each. Q.

12.† Show that the pressures of two balancing columns of the heights, H and h, are not, under ordinary circumstances, exactly equal, but differ by a small amount, equal to the pressure of a column of air of the height, $H - h$.

13.† State the magnitude and sign of the correction for the pressure of a column of air in some special case (*e.g.*, when a column of water differs in height by 800 mm. from its balancing column, in air 800 times less dense than water).

14.‡ Describe a mercurial manometer, and show how it can be used for measuring differences of pressure. D. 228.

15. Find the difference of pressure (in gravitation units) necessary to maintain a difference of level of 1 cm., 100 cm., etc., in a manometer containing mercury of the density 13.6. Prob. Q.

16. Describe a "multiple branch manometer," and state its advantages and disadvantages. D. 224.

XL.

ATMOSPHERIC PRESSURE.

1.‡ Describe a (BOURDON) metallic pressure-gauge, and the process of calibrating such a gauge by a mercurial manometer. D. 226 (225).

2.† In stating that the pressure of a liquid is proportional to the depth, what assumption is made as to the pressure at the surface of the liquid?

3. If the pressure (due to atmospheric or other influences) at the surface of a liquid, instead of being zero, is P, what correction must be made in the last statement? D. 141.

4.† Explain how, in the method of graduating a pressure-gauge, the correction in the last question might be overlooked.

5.‡ Describe one or more experiments with pressure-gauges, showing that pressures exist lower than that of the atmosphere.

6.† State reasons why a vacuum, rather than the atmosphere, should be taken as representing the zero of pressure. (D. 191?).

7.† What modification is necessary to convert a (BOURDON) pressure-gauge into an Aneroid barometer?

8.‡ Describe the Aneroid barometer as usually constructed. D. 206.

9.‡ Describe the construction of a simple form of mercurial barometer (the "Torricellian experiment") and state what facts it illustrates. D. 196, 197, 200.

10.* Give some idea of the average height of the barometric column at the sea level in inches and in centimetres. D. 197.

11.* How is the atmospheric pressure at a given time and place measured? Prob. D. 197.

12. Find the atmospheric pressure (in gravitation units) which will sustain 76 cm. of mercury of the density, 13.596. Prob. Q.

13.† Define a pressure of "one atmosphere" according to French, and more or less general scientific usage. (D. 198).

14. Calculate the force on a given surface (*e.g.*, the human body) due to atmospheric pressure. Prob. Q.

15.‡ Describe one or more experiments illustrating effects of atmospheric pressure (*e.g.*, Magdeburg hemispheres, burst membranes, mercury forced through wood, fountain in vacuo, etc.). D. 236.

16. Find the height of a column of air of density, .0012, which will exert a pressure of "one atmosphere" (76 cm., mercury of density, 13.6). Prob. Q.

17. What is meant by the "height of the homogeneous atmosphere?" D. 210.

18. Describe and explain (PASCAL'S) experiments in ascending hills with a barometer. D. 199.

19. Find the difference in pressure (in gravitation units) between two points on a mountain differing 10, 100, 1000, etc., metres in altitude, when the mean density of the atmosphere is .0012. Prob. Q.

20. Apply the last question to points higher up on the mountain, where the density of the air becomes .0011, .0010, .0009, .0008, .0007, or even .0006. Prob. Q.

21. Explain the estimation of heights by the barometer, the necessity of taking into account the density of the air, its variations, if considerable, and the use of tables in this connection. D. 209.

22. What relation usually exists between the fluctuations of a barometer and meteorological changes? D. 215.

23. What relation exists between the height of the mercurial barometer and that of one containing water or other liquid? D. 197.

XLI.

FLOW OF LIQUIDS AFFECTED BY AIR PRESSURE.

1.‡ Describe a "pipette," (or tube closed by the finger at one end), and explain the agency of the atmosphere in sustaining the weight of the liquid, and in transmitting it to the place where it is felt. (D. 269).

2.‡ Describe one or more experiments illustrating the principle of the pipette. D. 269.

3.‡ Describe and explain the action of an "intermittent fountain." D. 270.

4.‡ Describe a "MARIOTTE'S bottle," and state the conditions under which it will give rise to a flow of water under constant pressure. D. 275.

5. State the uses of a MARIOTTE'S bottle for obtaining constant pressure or constant suction. D. 275.

6. Find the pressure (or suction) due to a liquid of density, d, issuing from a MARIOTTE'S bottle, if h is the height of the inlet above the outlet. Prob. Q.

7.‡ Describe and explain the action of a "siphon." D. 271.

8. What relation exists between the height of a barometer filled with a given liquid and the maximum height through which that liquid can be raised by an ordinary siphon? Prob. Q.

9. Why must air be excluded from a siphon? and through what device is this accomplished in small siphons? in large siphons? D. 271.

10. Explain the "vase of Tantalus," and state the conditions of intermittent flow in terms of the rates of flow into and out of the vase. D. 274.

11. Give a possible explanation of certain intermittent springs. D. 275.

12‡ Describe and explain the action of a SPRENGEL pump. D. 240.

XLII.

PUMPS.

1. What connection exists between the height of a barometer filled with a given liquid and the maximum height to which the liquid can be raised by a suction pump? D. 255.

2. Find the maximum height to which water (of density. 1) can be sucked under atmospheric pressure (1033 grams to the sq. cm.). Prob. Q.

3.‡ Draw a diagram of an ordinary suction-pump (showing the barrel, piston, and two valves). D. 254.

4.* Name the essential parts of a suction-pump, and explain its action. D. 254.

5.† Show that an ordinary suction-pump is identical in principle with one of the simpler forms of air-pump, and that it is used as an air-pump in the first stages of raising water. Prob. D. 229, 254.

6.*† State the use of wetting the valves of a pump in the first stages of raising water.

7.† What modifications are necessary to convert a suction-pump into a force-pump? D. 258, 259.

8. What is meant by a "plunger," and in what respect does it differ from an ordinary piston? D. 259.

9.‡ Draw a diagram of an ordinary force-pump, and state its advantages over a suction-pump.

10. Show that a force-pump should not be inferior to a suction-pump, even when suction alone is required. Prob. Q.

11.† Show that a force-pump can be used either for exhausting or for compressing air, or other gases. (D. 243).

12.‡ Draw a diagram of an air-pump with three valves, and state its practical advantages. (D. 235).

13.† Show that the two sides of a piston of any pump, raising a liquid of density, d, through the vertical height, h, between two levels (the atmospheric pressure being practically the same at each level) are subject to a difference of pressure, hd.

14.† Find the force due to difference of pressure on the two sides of the piston in the last question, if its area is a, also the work, w, necessary to move it against this force (neglecting friction) through the distance, s. (D. 256).

15. Find the volume, v, and weight, w, of liquid delivered in the last question by the stroke, s, and calculate the work utilized in raising it to the height, h. Prob.

16. Show that the principle of work applies either to suction or to force-pumps. Prob. Q.

17.‡ Explain the construction and use of a hydraulic press. D. 142, 264.

18. Find the force, F, upon the large piston of area, A, in a hydraulic press, due to the force, f, on the small piston of area, a, (at the same level as the large piston). Prob. Q.

19. Find the distance, d, through which the large piston of area, A, moves when the small piston, of area, a, advances through the distance, D, (assuming the liquid incompressible). Prob.

20. Show that the principle of work applies to the hydraulic press. D. 143.

21.† What assumption (as to the levels of the two pistons) is made in elementary discussions of the hydraulic press?

22.† Show how, by the use of a counterpoise, corrections due to differences of level in a hydraulic press may be eliminated.

23. What, in general, is the effect of increasing the pressure at a given point in a fluid, by the amount, P, upon the pressure, p, at any other point? D. 141.

24. What is meant by transmissibility of pressure in fluid systems? D. 141.

XLIII.

CENTRES OF PRESSURE AND BUOYANCY.

1. How do you find the magnitude of the force exerted by a liquid upon a plane surface of variable depth? D. 150, 151.

2. Define centre of pressure. D. 150, 151.

3. How do you find the centre of pressure on any plane surface of variable depth? D. 151.

4. Where is the centre of pressure upon a dam? and where should a single prop be applied to resist this pressure? Prob. Q.

5. Where is the point of application of the forces exerted by a liquid on a body immersed in it? on a body floating upon the liquid? D. 153.

6. Define centre of buoyancy. D. 153.

7. State the conditions of equilibrium between the forces due to the weight of a body and the buoyant action of the fluid in which it is submerged. D. 155, 156, 157.

8. Show that the conditions in the last question do not hold for a body floating on the surface of a liquid. D. 157.

9. State the conditions of stable and unstable equilibrium, for bodies floating on a liquid, in terms of the path of their centres of gravity, due to rotation of the bodies, with constant volume immersed. Q. XXV. 17.

10. Explain the equilibrium of a boat with its centre of gravity above the centre of buoyancy. D. 157.

11.† Prove that the stability of a boat is always increased by lowering the centre of gravity. (D. 158).

12.* Explain the use of ballast. Q.

13.‡ State the advantages of the form and distribntion of weight in an ordinary hydrometer.

XLIV.

FLOTATION.

1.* A body of uniform density is immersed in a fluid; state the conditions which determine whether it will rise, sink, or remain where it is, when free to move. D. 155.

2.‡ Explain the action of the "Cartesian diver." D. 156.

3. Show that the Cartesian diver, in the middle of a fluid, is never in stable equilibrium, as far as height is concerned. D. 156.

4. Under what conditions will a body, denser than a liquid, float upon its surface?

5. Show that the principle of the last question can be extended to the case of bodies supported on the surface of a liquid by surface tension. D. 159.

6.† A body of density, d, floats on a liquid, of density, D; find the proportion of its volume immersed.

7. A body of density, d, and volume, V, floats with a volume, v, immersed in a liquid; find the density, D, of the liquid. Prob. Q.

8. A body floats either with a volume, v, immersed in a liquid of density, D, or with a volume, V, immersed in a liquid of density, d; find the relative densities of the liquids in terms of these volumes. Prob. Q.

9.‡ Describe the construction and use of a "specific volume-nometer," (or hydrometer with uniform scale showing reciprocals of density).

10. What, in general, is meant by a hydrometer of variable immersion? D. 168, 171.

11.† State the advantages of using a set of hydrometers instead of a single hydrometer, covering a given range of density.

12.‡ Describe a "densimeter" (or hydrometer with specific gravity scale), and the peculiar spacing of the scale of such an instrument. D. 172.

13. Name certain arbitrary hydrometer scales, and explain the use of tables in connection with these scales. D. 173, 174.

14. State the advantages, for special purposes, of instruments like the "centesimal alcoholimeter." D. 175.

15. What is meant by a hydrometer of constant immersion? D. 168.

16.‡ Describe NICHOLSON'S hydrometer, and the general method of finding by it the weight of a body (in air or in water). D. 169.

17. Show that any uniform pressure (whether due to the atmosphere or not) will not affect the equilibrium of a hydrometer. Prob. Q.

18. Show that any cause which increases the pressure on the lower part of a hydrometer more than on the upper part will have a buoyant effect. Prob. Q.

19.‡ Describe and explain one or more experiments illustrating the buoyant effect of covering the upper portion of a hydrometer, floating in water, with a liquid of lower density.

20.† State the effect of atmospheric density on a hydrometer, and the advantage of reducing the dimensions of those parts of a hydrometer which float above the surface of a liquid.

XLV.

PRINCIPLE OF ARCHIMEDES.

1. Prove that the difference between the forces exerted upon the top and bottom of a rigid column with vertical sides of height, h, including an area, a, by a fluid of density, d, must be the same as that (hda) upon a column of the same fluid having identical dimensions, and hence equal to the weight of the column of fluid. D. 153.

2. Show that the buoyant action of a fluid upon a rigid column, with vertical sides, is independent of the depth. D. 153.

3. Prove (by cutting up a body into prismatic columns with vertical sides) that any body, suspended in a fluid, must be buoyed up with a force equal to the weight of an equal bulk of the fluid. D. 153.

4. Prove the statement in the last question by substituting for the body, a body of the fluid having the same shape, and applying the general conditions of equilibrium. D. 153.

5. What is meant by the loss of weight of a body when immersed in a fluid? D. 153.

6.* State the principle of Archimedes. D. 153.

7. Show that the principle of Archimedes holds for any fluid, whether liquid or gaseous. Prob.

8.‡ Explain how the weight of a body in water can be found by a NICHOLSON'S hydrometer, (1) if its density is greater, and (2) if its density is less than that of water. (D. 169).

9.† When is the weight of a body in a fluid considered positive, and when negative?

10.† Show that the principle of Archimedes applies to all bodies, whether their density be greater or less than that of the fluid in which they are immersed.

11.‡ Describe one or more forms of hydrostatic balance. D. 164.

12.‡ Explain the use of a sinker in weighing bodies in a liquid in which they would otherwise float, and how the weight of the sinker can be allowed for. D. 165.

13.‡ Describe the "overflow-beaker," and its use for finding the weight of liquid displaced by a solid.

14.‡ Show that the weight of an overflow beaker is not increased when a suspended solid is immersed in it. Prob.

15.‡ Show that a vessel (without overflow), into which a suspended solid is immersed, gains in weight by an amount equal to the weight of liquid displaced by the solid. Prob.

16.* Prove (by considering the weight of a solid, as borne partly by its suspension, and partly by the vessel in which it is immersed) that the loss of weight of a body on immersion must necessarily be equal to the gain of weight of the vessel in which it is immersed. Prob.

17.*‡ Describe one or more experiments illustrating the principle of Archimedes. D. 154.

18.* A piece of chalk weighs (1) 5 grams in air when dry, and (2) 2 grams in water; but (3) it weighs 6 grams in air when the air in its pores has been completely replaced (through long soaking) by water, and (4) it weighs 3 grams under the same circumstances in water; show that if any three of the four data above are given, the fourth (assuming the chalk to be inexpansible) can be supplied. Prob.

19.† Discuss the truth of the statement that "water weighs nothing in water."

20.* When does absorption of water increase the weight of a body in water, and when does it have no effect? Q.

21.*‡ Describe one or more experiments with a rigid vessel and with an expansible vessel, illustrating the point in the last question.

22. Why was ARISTOTLE'S method of detecting the weight of air unsuccessful? and how should it have been modified? Prob. (D. 195).

XLVI.

ATMOSPHERIC BUOYANCY.

1. About what is the weight of a cubic centimetre of air? of a litre? of a cubic metre? etc. (D. 195).

2. Calculate the lifting power of a balloon of weight, w, volume, v, filled with gas of density, d, in air of density, D. D. 249.

3.‡ Describe an experiment with the "baroscope." D. 247.

4.‡ Describe a "barodeik" or graduated baroscope, and explain its action.

5.† What is meant by the "effective weight" of a body in a fluid?

6. Find the effective weight (in gravitation units) of a body of mass, M, and density, D, in air of density, d. Prob. Q.

7. Find the effective weight (in gravitation units) of M grams of brass of density 8.4 in air of density 0.0012 (grams to the cubic centimetre). Prob. Q.

8. Under what circumstances are standards of weight supposed to be adjusted? D. 251.

9.† Show that all ordinary weighings consist in balancing effective weights in air.

10.† What is meant by the "apparent weight" of a body (in air)? D. 251.

11.† Show that the effective weight of a body is always less than its apparent weight by a certain proportional amount (about 1 part in 7000) depending only upon the density of the air (say 0.0012) and of the brass weights (say 8.4) by which it is counterpoised. D. 1.

12. Given the apparent weight, W, and density, D, of a body counterpoised by brass standards of density, D', in air of density, d, find the true weight of the body in vacuo. D. 251.

13. When is the correction for buoyancy positive and when negative? Prob. Q. 11.

14.† Illustrate the corrections for air-buoyancy by numerical examples.

15. Show that the apparent weight of a body in air varies according to conditions of atmospheric density, and that, therefore, all exact weighings should be reduced to vacuo. Prob. (D. 160, 251). Q. 11.

16. Prove that the effective weight of a body in water is less than in air by an amount equal to the difference between the weights of water and of air displaced, and hence equal to the effective weight of the water displaced. Prob. Q.

17. Prove (by considering the relation between effective and apparent weights) that the statement in the last question applies to apparent as well as to effective weights. Prob. Q. 11, 14.

18. Show that the principle of Archimedes applies to effective or to apparent weights, as well as to true weights. Prob. Q.

XLVII.

APPARENT SPECIFIC GRAVITY.

1.† What name is given to the ratio between the apparent weight of a given substance and the apparent weight of an equal volume of water, or other standard of reference?

2.* Define "specific gravity," and distinguish it from density. D. 160.

3.† Define "apparent specific gravity," and distinguish it from density as well as from true specific gravity.

4.† What substance, or substances, are chosen as standards of reference for specific gravity (1) in the case of liquids or solids and (2) in the case of gases? (D. 160).

5.† Criticise the common use of the term "vapor density" (as synonymous with specific gravity).

6.† At what temperature did the founders of the metric system intend that the density of water should be exactly 1, and at about what two temperatures is this condition now thought to be fulfilled? (D. 160).

7.† Give some idea of the density of water at ordinary temperatures, and of the delicacy of the apparatus necessary to detect variations in its density.

8. Given that a cubic decimetre of wood weights 499 grams in air, and 500 grams in vacuo; also that a cubic decimetre of water at a certain temperature weighs 997 grams in air, and 998 grams in vacuo; find the density of the wood, and its true and apparent specific gravities referred to water at the given temperature. Prob. Q.

9.*‡ Explain the determination of (apparent) specific gravity by means of a (JOLLY) spring balance, or by a hydrostatic balance. D. 164.

10. Given the (apparent) weights, W and w, of a body in air and in water, how do you find the (apparent) specific gravity of the body? D. 164.

11. If W is the (apparent) weight of a body in air, how do you find its (apparent) specific gravity if w is (1) the (apparent) loss of weight of the body when weighed in water? (2) the (apparent) gain in weight of the vessel in which it is immersed? or (3) the (apparent) weight of the water displaced? (D. 164).

12*†A piece of dry chalk weighs 5 grams in air, and 2 grams in water, but it takes 1 gram of water to replace all the air in its pores; find the (apparent) specific gravity (1) of the dry chalk, (2) of the wet chalk, and (3) of the material within which the pores of the chalk are included.

13. How do you find the (apparent) specific gravity of a liquid, if W and w are respectively (1) the (apparent) losses of weight of a given body when immersed in water and in the liquid, (2) the corresponding (apparent) gains in weight on the part of the vessel, or (3) the (apparent) weights of water and of liquid displaced by a given body? Prob. (D. 166).

14.*‡Explain the determination of (apparent) specific gravity by means of a specific gravity bottle. (D. 163).

15.* A vessel is filled by an (apparent) weight, W, of water or by an (apparent) weight, w, of a given liquid; find the (apparent) specific gravity of the liquid. (D. 163).

XLVIII.

LAW OF AVOGADRO.

1.† What is meant by the molecular constitution of matter?

2.† State the law of chemical combining proportions of gases in terms of their volumes.

3.† What conclusions have Chemists adopted in regard to the number of molecules in a given volume of different gases at the same pressure and temperature?

4.† State the law of Avogadro.

5.† What is meant by the molecular weight of a gas?

6.† Find the relation between the molecular weight of a gas and its specific gravity referred to hydrogen, assuming that the molecular weight of hydrogen is 2.

7. Given the density of a gas, how do you find its molecular weight? Illustrate by the following examples:

Density of	hydrogen	(0°	and	76 cm.)	0.00008952
"	" oxygen	"	"	"	0.0014291
"	" nitrogen	"	"	"	0.0012544

Prob. Q.

8.‡ Explain one or more methods (*e.g.*, DUMAS') for determining the molecular weight of a gas (or vapor).

XLIX.

MOLECULAR THEORY OF THE PRESSURE OF GASES.

1.† Through what agency is the pressure of a gas believed to be maintained?

2.† Show that, if pressure is maintained by molecular impact, it should vary as the number of molecules in a given space, provided that the molecules are not so near together as to interfere with one another.

3. State DALTON'S law for gaseous mixtures, and its applicability in certain cases to mixtures of vapors and gases. D. 227.

4.‡ Describe one or more experiments illustrating DALTON'S law.

5.† What necessary relation exists between the number of molecules in a given space and the density of a gas?

6.† Show the pressure of a gas, if sufficiently rare, must vary as its density.

7.† State results of experimental investigation as to the truth of the statement in the last question.

8. What conclusion did DULONG and ARAGO arrive at with respect to the compressibility of air? D. 219.

9.† Within what limits have the results of DULONG and ARAGO been confirmed by later experiments? (D. 219).

10.† Name certain gases in which the density is found to be at least approximately proportional to the pressure for variations of one or two atmospheres.

L.

LAW OF BOYLE AND MARIOTTE.

1. State the necessary relation between the density and the volume of a given mass of gas. Prob.

2. Prove that, according to the molecular theory of the pressure of a gas, the pressure must vary inversely as the volume. Prob. Q.

3.* State the law of BOYLE and MARIOTTE. D. 217.

4. Show that the product, VP, of the volume, V, and the pressure, P, of a given mass of gas, obeying the law of BOYLE and MARIOTTE, is constant. Prob. Q.

5.‡ Describe an experiment with BOYLE'S or MARIOTTE'S tube, illustrating the law of BOYLE and MARIOTTE. D. 218.

6.‡ Describe an experiment with a mercury well, showing that the law of BOYLE and MARIOTTE holds for pressures less than that of the atmosphere. D. 218.

7.‡ Describe one or more experiments with a piece of apparatus capable of illustrating the law of BOYLE and MARIOTTE for pressures both greater and less than that of the atmosphere.

8. Describe and explain the use of one or more forms of compressed air manometer. D. 225.

LI.

UNEQUAL COMPRESSIBILITY OF GASES.

1.† What limit would the volume of an ideal gas approach if the pressure should become indefinitely great? and how would this limit be modified in practice if the molecules of the gas were incompressible, and occupied a certain amount of space?

2.† Show that the size of molecules would diminish the compressibity of a gas.

3.† What would be the effect of attractive forces between the molecules of a gas on the volume occupied at a given pressure?

4.† Show that forces of the nature of adhesion or cohesion would tend to increase the compressibility of a gas.

5. Explain the departure of certain gases from the law of BOYLE and MARIOTTE. Prob. Q.

6. Describe one or more experiments (due to DESPRETZ, POUILLET, or REGNAULT) showing the unequal compressibility of different gases. D. 219, 220, 221.

7.† Give some idea of the percentage error in calculating the density or pressure of the more permanent gases, by the law of BOYLE and MARIOTTE, within limits of one or two atmospheres.

LII.

VAPORS AND GASES DISTINGUISHED.

1.‡ Describe the effects of increasing pressure upon the volume of a vapor.

2.† What is meant by the "maximum pressure" (or tension) of a vapor?

3.† What is meant by the condensation of a vapor?

4.† Distinguish vapors from gases in respect to phenomena of condensation.

5.† Distinguish between the condensation of a vapor and the absorption of a vapor by a liquid.

6. What is meant by the solubility of a gas or vapor in a liquid at a given pressure and temperature? D. 228.

7.† State the law connecting the solubility of a gas or vapor in a liquid with the pressure.

8. Describe one or more experiments illustrating the absorption of gases or vapors by charcoal. D. 228.

9.† What is meant by the occlusion of a gas?

10.‡ Describe one or more experiments illustrating the occlusion of hydrogen by platinum or iridium. (D. 228).

11.‡ Describe one or more experiments showing that a film of air adheres to glass or other solids under certain conditions. (D. 228).

12.† What connection probably exists between the causes giving rise to phenomena of condensation, absorption, occlusion, solubility, etc., in certain gases or vapors, and their departure from the law of BOYLE and MARIOTTE?

END OF PART I.

QUESTIONS ON GENERAL PHYSICS.

PART II.—HEAT.

LIII.

THERMOMETRY.

1.*†Discuss the temperature of the human body as indicated by a Centigrade thermometer, the variation in temperature between different parts of the skin exposed, the conditions under which bodies seem warm or cold to the touch, and the reasons why the sense of touch cannot be relied upon as an indication of temperature. (D. 276).

2.* When are two bodies said to be at the same temperature, and when is one of the bodies said to have the higher temperature? D. 277.

3.† What relation is believed to exist between temperature and energy of molecular vibration?

4.* Describe the construction of a mercurial thermometer. D. 281, (1 and 2).

5.* What are meant by the fixed points of a thermometer? D. 281, (3).

6.* How are the fixed points of a thermometer usually determined? D. 281, (3).

7. Explain the fact that most thermometers read a fraction of a degree above 0° in melting ice. D. 284.

8.† Does the gradual contraction of the bulb of a thermometer in the course of time affect the zero alone, or does it affect all readings alike?

9.* How would you reduce the readings of a Fahrenheit thermometer (or those of a Réaumur thermometer) to the Centigrade scale,or the reverse? D. 283.

10. What advantages does an alcohol thermometer possess over a mercurial thermometer (and the reverse)? D. 286.

11.† Describe an ordinary medical maximum thermometer.

12. Describe a (Six's) maximum and minimum thermometer. D. 287.

13. Describe a (Rutherford's) minimum alcohol thermometer. D. 287.

14. Describe one or more forms of metallic thermometer. D. 289, 290.

15. How is a differential air-thermometer constructed? D. 291.

LIV.

EXPANSION OF GASES.

1.* Describe one or more experiments showing that gases expand when heated.

2. Explain the draft of chimneys. D. 330.

3. Describe (Gay-Lussac's, or) any simple form of thermometer depending upon the expansion of air at constant pressure. D. 319, 323.

4.‡ Describe the use of the apparatus in Q, L. 7, for the measurement of the expansion of a gas at constant pressure. L.

5. Show that the results obtained with an air-thermometer are (slightly) affected by the expansion of the glass of which it is composed. D. 319.

6. State the effect of moisture in experiments relating to the expansion of air. D. 319.

7. Explain how leakage of air by a mercurial index may vitiate results when such an index is used. D. 319.

8. Name certain sources of error in air-expansion thermometers. Q. 5, 6, and 7.

9. What is meant by the coefficient of expansion of air at constant pressure? D. 319.

10.† 273 cu. cm. of air expand under the constant pressure of one atmosphere so as to occupy 373 cu. cm. when heated from 0° to 100°; find the coefficient of expansion in question. Prob. Q.

11. Explain Regnault's air-pressure thermometer. D. 320.

12.‡ Explain the use of the apparatus in Q. L. 7 (see Q. 4), for the measurement of the increase of pressure of air confined to a constant volume.

13. Criticise the expression "coefficient of expansion at constant volume." D. 320.

14. What is meant by the "coefficient of increase of pressure" of a gas? D. 320.

15.† The pressure of a gas increases from 27.3 inches of mercury to 37.3 inches of mercury when it is heated at constant volume from 0° to 100°; find its coefficient of increase of pressure. Prob. Q.

16.† Explain the increase of pressure with temperature in a gas according to the molecular theory. Q. XLIX. 1, LIII. 3.

17. Is the coefficient of expansion equal to, greater than, or less than the coefficient of increase of pressure (1) in gases obeying the law of BOYLE and MARIOTTE, (2) in gases showing undue compressibility, and (3) in gases which are less compressible than a perfect gas? D. 320, 321, (222).

18. Name a gas in which the coefficient of expansion is less than its coefficient of increase of pressure, and other gases in which the reverse is true. D. 321.

LV.

ABSOLUTE TEMPERATURE.

1. Give reasons for adopting the expansion of gases as a standard for the measurement of temperature. D. 323.

2. How is absolute temperature usually defined? D. 325.

3. What is supposed to become of the volume of a perfect gas cooled under constant pressure to about $-273°$, and why? D. 325.

4. What is supposed to become of the pressure of a perfect gas cooled under constant volume to about $-273°$ and why? D. 325.

5. What practical limitations apply to the statements in Q. 3 and 4? And which one of these applies to Q. 3, and not to Q. 4? D. 325.

6. State one or more advantages which would be derived from an alteration of the definition of absolute temperature so that it should depend upon the pressure, not the volume of a gas. D. 325; Q. 5.

7. What is meant by the "absolute zero" of temperature? D. 325.

8. How do you convert absolute into ordinary temperatures, or the reverse? D. 325.

9.† State the law (of CHARLES) connecting the volume and the absolute temperature of a perfect gas at constant pressure.

10. What relation exists between the volume, V, the absolute temperature, T, and the pressure, P, of a given mass of gas? D. 325.

11. What relation exists between the pressure, P, density, D, and absolute temperature, T, of a gas? D. 325, Q. 10.

12. Given the density, D_1, of a gas at the pressure, P_1, and temperature, t_1, (above freezing): how do you find its density, D, at any other pressure, P, and temperature, t? Prob. Q. 8 and 11.

13. Explain the converse of the last question. Q.

14. Given that the density of air is 0.001293 at 0° and 76 cm., how do you find its density at any temperature, t, and pressure, p? Q.

15. How do you reduce the volume, V, of a gas at the temperature t, and pressure, p, to 0° and 76 cm.? Q.

LVI.

EXPANSION OF LIQUIDS.

1.‡ Explain DULONG and PETIT'S method for measuring the expansion of a liquid by balancing columns. D. 306, 307; L.

2.† Show that the results obtained as in Q. 1 are independent of the diameter of the tubes employed, and hence independent of any change in the diameter of these tubes due to expansion. Q. XXXVIII.

3.† A column of liquid of height, H, and temperature, T, balances one of height, h, and temperature, t; find the mean coefficient of expansion from t to T, in terms of the volume at t as a standard.

4.† Distinguish the apparent expansion of a liquid contained in a vessel from its real or absolute expansion. D. 295.

5.† What is the approximate relation between the coefficient of apparent expansion, a, that of real expansion, r, and the coefficient of (volume) expansion of the vessel, v, in which the liquid is contained? D. 295.

6. Given the coefficient of real expansion of any liquid, such as mercury (determined as in Q. 1), how can you find the coefficient of expansion of a specific gravity bottle, or other vessel of definite capacity? D. 308.

7. Explain the determination of the coefficient of expansion of a liquid by means of a specific gravity bottle of known coefficient of expansion. D. 310.

8. Describe the construction and principal uses of a weight-thermometer. D. 300, 316.

9. How can the coefficient of expansion of any liquid be determined by means of a calibrated thermometer-tube? D. 309.

10. State in general terms the dependence of the coefficient of expansion of liquids upon the temperature. D. 311.

11. Describe the expansion of water from 0° to 100°. D. 312.

12. State certain points of difference between the expansion of sea-water and ordinary water. D. 313.

LVII.

EXPANSION OF SOLIDS.

1. What relation exists between the coefficients of linear and cubical expansion for a given substance under given conditions? D. 293.

2.† Describe some form of apparatus for measuring the linear coefficient of expansion of solids. D. 303; L.

3. Give some idea of the range of linear coefficients of expansion for metals (and building materials in general). D. 303.

4. State certain practical applications of the forces brought into play by the expansion or contraction of solids. D. 305.

5. Explain the construction of a compensating metallic ("gridiron") pendulum. D. 304.

6.† How is the compensating balance-wheel of a watch or chronometer constructed?

7. Explain the action of one or more forms of thermometer depending upon the difference in expansion between two metals. D. 289, 290; Q. LIII., 14.

8. Describe a (Graham's) compensating mercurial pendulum, and explain the principle upon which it works. D. 304.

LVIII.

EVAPORATION AND CONDENSATION.

1.* What is meant by evaporation? D. 366.

2. Give some idea of the volume of vapor formed by a given mass of liquid (*e.g.*, water). D. 413.

3.* State the influence of temperature upon the rapidity of evaporation. D. 366.

4.† Compare and explain relative rates of evaporation in air and in vacuo.

5.* How does moist air compare with dry air in its influence upon the rate of evaporation of water?

6. Why are currents of air favorable to evaporation? D. 396.

7.† Show that air-currents should be considered not as accelerating drying processes more, but as retarding them less, than still air.

8.* What is meant by the statement that a certain space is "saturated" with a vapor? D. 368.

9. What is meant by the "maximum pressure" of a vapor, or by its "maximum density," at a given temperature? D. 368.

10.‡ Describe an experiment illustrating the fact that the pressure of the vapor of a liquid, when maintained at a constant temperature in a confined space, reaches a maximum. D. 368.

11. What is meant by a "non-saturated" or "superheated" vapor (*e.g.*, superheated steam)? D. 369.

12.† What happens when a vapor at its maximum pressure (or at its maximum density) is caused to expand at a constant temperature? (D. 368).

13. What happens when a vapor at its maximum pressure (or density) is compressed at a constant temperature? D. 368.

14.‡ Describe an experiment illustrating the point in the last question. L.

15.*What name is given to the transformation of a vapor or a gas into a liquid?

16. Describe a "still," and state what is meant by "distillation"? D. 395.

17. Describe one or more methods of liquefying gases. D. 371, 372, 381.

(See Questions LII.)

LIX.

HYGROMETRY.

1. What is meant by the "relative humidity" of the air? D. 416.

2. What is meant by the "dew-point" of air? D. 418.

3. Show that the dew-point of air at constant volume differs from the (ordinary) dew-point at constant pressure. D. 418.

4. What is meant by a "hygroscope" or "hygrometer of absorption?" D. 420, 421.

5. Describe a (REGNAULT'S or a DANIELL'S) dew-point hygrometer, or any instrument serving the same purpose. D. 423-426.

6. What is meant by a "wet-bulb thermometer," or by a "wet-and-dry-bulb hygrometer?" D. 427.

7.† Show that a wet-bulb thermometer cannot stand higher than the dry-bulb thermometer, nor lower than the dew-point.

8.† Given that 0.0003 units of heat affect the temperature of one cu. cm. of ordinary air by one degree (see Q. LXVIII.), and that one gram of cold water requires 600 units of heat to convert it into vapor (D. 415), how many grams of water must evaporate into one cu. cm. of air in order that it may be cooled from 21° to 15°? Prob. (D. 428).

9.† Given that air can be cooled, by the evaporation of water, from 21° to 15° and no more; that the evaporation of .000003 grams of water into each cu. cm. of air is sufficient to account for this cooling; but that .000013 grams of moisture are necessary to saturate a cu. cm. of air at 15°; how much moisture do you infer to be originally present in each cu. cm. of air?

10. Explain the possibility of estimating the amount of aqueous vapor in the atmosphere from the readings of wet and dry-bulb thermometers. Prob. Q. 8 and 9.

11. If a cu. cm. of air could contain .000018 g. of moisture and does contain .000010 g., what is its relative humidity? Q. 1.

12. Given that the dew-point of air containing .000010 g. of moisture to the cu. cm. is 10°, and that the readings of the wet and dry-bulb thermometers in this air are 15° and 21° respectively; how does the excess of the dry-bulb thermometer over the dew-point compare with its excess over the wet-bulb thermometer? Prob.

13. Explain the use of Glaisher's factors for the estimation of the dew-point from readings of wet and dry-bulb thermometers. D. 427.

14.† Show that the use of Glaisher's factors cannot be extended to extreme limits of dryness.

15.† Which one of Glaisher's factors is most commonly employed?

16.† State an empirical law for finding, under ordinary conditions, the dew-point, p, when the readings of the dry and wet-bulb thermometers are d and w, respectively. Prob. Q.

17.† Give some idea of the amount of moisture in a cu. cm. of air saturated at different temperatures.

18. Explain the use of a chemical hygrometer. D. 429.

19. Given that 0.000,001,06 grams of moisture in a cu. cm. of space exert a pressure of 1 mm. of mercury, how would you find the pressure due to m grams of moisture in 1 cu. cm. of air? Prob. Q. XLIX., 2, 3.

20. Give some idea of the pressure of aqueous vapor in air saturated with it at different temperatures. D. 400.

21.† Given the pressure, p, of aqueous vapor in moist air at the temperature, t, and total pressure, P; also the fact that aqueous vapor is only five-eighths as dense as air; how do you find (1) the pressure due to the dry air, alone? (2) the weight of dry air in a cu. cm. of space? (3) the weight of aqueous vapor in the same space? and (4) the density of the moist air? Prob. Q.

22. How can hot and cold air, neither completely saturated with moisture, form a mixture which precipitates moisture? D. 435.

23.‡ Describe one or more experiments with the air-pump, showing that sudden rarefaction of air may cause partial precipitation of the moisture which it contains.

24.† How is the result in the last question modified by the absence of dust?

25. State some of the probable causes of atmospheric precipitation. Q.

LX.

PRESSURE OF VAPORS.

1.‡ Describe one or more forms of apparatus for measuring the maximum pressure of vapor caused by the introduction of a liquid at different temperatures into the Torricellian vacuum. D. 398, 399.

2.† Explain how the correspondence between the temperature and pressure of steam in a boiler may be tested by means of a thermometer and manometer.

3.‡ Describe the construction and use of a simple form of apparatus for determining pressures of vapors at different temperatures, whether these pressures are above or below that of the atmosphere.

4. How would you plot a curve to illustrate results obtained as in the last three questions? D. 369.

5.† Explain the use (or interpretation) of a curve representing pressures of vapor at different temperatures.

6. Give some idea of the pressure of steam at different temperatures. D. 400.

7. How do the pressures of volatile and non-volatile liquids compare at a given temperature? D. 403.

8. State the common characteristics of curves representing pressures of vapors at different temperatures. D. 401.

9.† Show that these curves do not differ so widely as might be supposed, if the boiling-point is taken in each case as the origin of co-ordinates in plotting the temperatures and pressures.

10. Give some idea of the number of degrees which liquids as a class must be heated above their boiling-points in order that the pressure may increase by 1 atmosphere, 2 atmospheres, etc. Prob. D. 382, 400, 403.

LXI.

CRITICAL TEMPERATURE.

1.† State the effect of increasing temperature upon the density of a vapor in contact with its liquid. (D. 369).

2.† What limit is approached by the density of a vapor in contact with its liquid as the temperature increases?

3. What name is given to that temperature at which a vapor becomes indistinguishable from its liquid? D. 380.

4. Define "critical temperature." D. 380.

5. State some of the symptoms of the approach of a liquid and its vapor to the critical temperature. D. 380.

6.† Distinguish the effects of increasing pressure on vapors and gases (1) above and (2) below their critical temperatures.

7.† Why is it necessary to cool the so-called "permanent gases" in order that they may be liquefied? Prob. Q.

8.† Give some idea of the critical temperatures of ordinary liquids and gases.

9.† Of two liquids, one having a higher critical temperature than the other, which has probably the higher boiling-point? And which has probably the greater coefficient of expansion?

LXII.

BOILING.

1.* Distinguish between evaporation and boiling. D. 382.

2.* Describe the general behavior of a liquid as it is gradually raised to the point of ebullition. D. 382.

3.* What is meant by the boiling-point of a liquid? D. 383, (1).

4.* Is the temperature of a pure liquid constant or variable while boiling? D. 383, (2).

5.† Does the statement in the last question apply to impure liquids or to mixtures?

6. How does the temperature of the vapor of a boiling liquid compare in constancy with that of the liquid? D. 383, (2).

7.† In testing the boiling-point of a thermometer, should the bulb be immersed in water or in steam?

8.† Describe one or more experiments illustrating the elevation of the boiling-point of a liquid above its normal. D. 391.

9. Under what circumstances does the phenomenon in the last question appear? D. 391.

10. Explain "boiling with bumping." D. 391.

11. What is meant by the "spheroidal state" of a liquid? D. 392.

12.‡ Describe one or more experiments illustrating the behavior of a liquid in the spheroidal state. D. 393, 394.

13. How does the pressure of the vapor of a boiling liquid compare with that of the atmosphere? D. 383, (3).

14.‡ Describe an experiment illustrating the point in the last question. D. 383, (3).

15.† Explain the determination of the boiling-point of a liquid by means of a U-tube closed at one end, and state some of the advantages of this method.

16. Define the boiling-point of a liquid in terms of external atmospheric pressure. D. 384.

17.† How would you find the boiling-point of a liquid from the curve representing the pressure of its vapor at different temperatures?

18. Show that the boiling-point of a liquid must vary with the external pressure. D. 385.

19. Give some idea of the effect of pressure on the boiling-point of water. D. 385.

20.† What approximate allowance should be made for the effect of abnormally high or low barometric pressure on the boiling-point of an unknown liquid? (Q. LX., 9; LXII., 19).

21.‡ Describe one or more experiments with the air-pump illustrating the dependence of boiling-point on pressure.

22.‡ Describe and explain Franklin's experiment, showing that a liquid may be made to boil by cooling its vapor. D. 386.

23. Explain the principle of the "hypsometer," (or instrument for measuring barometric heights by the variation in the boiling-point of water). D. 387.

24. Explain Papin's "Digester," (or any instrument for cooking in water above 100°). D. 388.

25. State the effect of most salts, when dissolved in water, on the boiling-point. D. 389.

26.† State the influence of molecular weight on the boiling-points of certain classes of saline solutions of a given strength.

27. Explain the rise of temperature in a boiling saline solution. D. 389.

28. When does a mixture of two liquids have a boiling-point between those of its two constituents? And when is the boiling-point lower than that of either constituent? D. 390.

LXIII.

FUSION AND SOLIDIFICATION.

1.* What is meant by melting or fusion? D. 347.

2.* What is meant by the melting-point (or temperature of fusion) of a substance? D. 347.

3.* Give some idea of the melting-points of different substances on the Centigrade scale. D. 347.

4. Distinguish solution, or the process of dissolving a solid in a liquid, from melting or fusion. D. 352.

5.* What is meant by the freezing-point (or by the temperature of congelation or solidification) of a substance? D 348, 354.

6.* What is meant by the "definite temperature" of freezing or melting? D. 348.

7.‡ Describe one or more experiments illustrating the possibility of cooling a liquid below its ordinary freezing-point without its freezing.

8. Describe one or more cases of solidification accompanied by crystalization. D. 357.

9. Describe Tyndall's "ice-flowers." D. 358.

10.† Describe one or more processes of crystallization from solutions, in ordinary use.

11.† What is meant by the solubility of a solid in a liquid?

12.† State the ordinary effects of temperature upon solubility, and name certain marked exceptions. (D. 352.)

13. What is meant by a "supersaturated solution?" D. 359.

14. Describe one or more experiments showing analogies between supersaturated solutions and liquids cooled below their freezing-points. D. 359; Q. 1–16.

15. Give instances of effects due to change of volume in freezing. D. 360.

16. What is the effect of pressure upon the melting-points of substances which like ice expand on freezing? and how is the effect modified in the case of substances which like wax, resin, etc., expand on melting? D. 361.

17.† Explain (in so far as possible without recourse to thermodynamics) the effects in the last question.

18.‡ Describe one or more experiments illustrating the viscosity (or plasticity) of ice. D. 363.

19. Describe certain facts connected with the formation and motion of glaciers, illustrating viscosity and regelation in ice. D. 365.

20.‡ Describe one or more experiments illustrating regelation. D. 364, 365.

21. Explain the flow of ice as the effect of pressure upon its melting-point. D. 362, 363.

22.* What is the effect of salt in solution upon the freezing-point of water?

23.† State the influence of molecular weight upon the freezing-points of certain classes of saline solutions of a given strength.

(See farther under Latent Heat, Q. LXIV.)

LXIV.

LATENT HEAT.

1.† Explain cooling by evaporation as the consequence of the assumption (Q. LIII., 3) that temperature depends upon average molecular velocity, and that the molecules of a liquid attract one another (Q. XXXV. LI. and LII.).

2.‡ Describe one or more methods of freezing water, mercury, or carbonic dioxide, illustrating the production of cold by evaporation. D. 373–379.

3. How is the temperature of a vapor or a gas affected by condensation? D. 373.

4. What relation exists between the heat produced by condensation and that absorbed by evaporation when the process is reversed? D. 373.

5.‡ Describe one or more experiments illustrating the production of cold by liquefaction or solution. D. 352, 353, 354.

6.‡ Describe an experiment showing that, in the sudden freezing of water cooled below its freezing point, heat is given out.

7.‡ Describe an experiment showing the development of heat in the crystallization of a supersaturated solution of hyposulphite of sodium.

8.† What points of analogy between liquefaction and solution can now be added to those mentioned under Q. LII., 14?

9. What relation exists between the heat given out in solidification and that which disappears in melting? D. 349.

10.‡ Describe an experiment in which a body receiving a uniform supply of heat is first melted, then raised to boiling, and finally converted into vapor. L.

11.† Draw a curve representing the temperature of the body in the last question at different points of time, and indicate how the curve should be extended in both directions.

12.† How do you account for the horizontal portions of the curve in the last question?

13. What is said to become of the heat flowing into a substance (during a change of state), when it has no apparent effect upon the temperature of that substance? D. 349.

14.* What name is given to the heat which appears or disappears in condensation, evaporation, solidification, or melting? D. 349, 373.

15.* What is meant, in general terms, by the *latent heat* of condensation, evaporation, solidification, or fusion? D. 349, 373.

16.† In which body (solid, liquid, or gaseous) are the heats of fusion and vaporization said to be latent? D. 349.

17.† Criticise the expression, "latent heat of ice." Q.

18.† Define the latent heat of fusion and the latent heat of vaporization in terms of the (average) quantity of heat necessary to raise one gram of water one degree, Centigrade. (Prob. D. 335, 350, 373).

19.† If it takes a uniform supply of heat x seconds to melt a quantity of ice at 0°, y seconds to raise the water formed by the melting of this ice from the freezing to the boiling temperature, and z seconds to convert the boiling water into steam at the same temperature, what are the latent heats of fusion and vaporization in question? (Prob. Q.).

20. Substitute in the last question 80 for x, 100 for y, and 537 for z; or any multiple of these numbers, the same for all. Prob. Q.

21. If the latent heat of steam is 537, and that of water is 80, how many kilograms of steam would be condensed and cooled to zero by the melting of 637 kilos of ice? And how many kilos of ice would be melted and raised to boiling by the condensation of 180 kilos of steam? Prob. Q.

22.† Are ordinary latent heats supposed to be determined under atmospheric pressure or in vacuo?

23. What is meant by the ordinary (not the "total") latent heat of steam at zero, or at any temperature? D. 415.

24.† Explain why the latent heat of steam at zero is greater than that at the boiling temperature (in view of the molecular work accomplished in the expansion of water).

25. How do the latent heats of water and of steam compare with corresponding latent heats for other substances? D. 530, 415.

26. State the influence of the great latent heat of water upon cold climates. D. 351.

27.† Show that the great latent heat of steam tends to moderate meteorological changes relating to humidity and precipitation.

LXV.

HEATS OF COMBINATION AND COMBUSTION.

1. What is meant by the "heat of combination" of one substance with another? D. 508, 509.

2. Two grams of zinc, dissolving in a test-tube surrounded by ice, and containing a mixture of sulphuric and chromic acids, cause 45 grams of the ice to melt. If the latent heat of water is 80, what is the heat of combination of the zinc with the acids in question? Prob. Q.

3. What are meant by heats of combustion? D. 509.

4. Two litres of coal-gas of the density, 0.0005, give out in burning heat enough to raise 20 grams of water from 37° to boiling, and to convert the 20 grams of boiling water into steam. If the latent heat of steam is 537, what is the heat of combustion of the coal-gas? Prob. Q.

5. Give some idea of the heats of combustion of different substances in oxygen. D. 509.

(See farther, Q. LXIX., 23, 24).

LXVI.

THERMAL CAPACITY.

1. Define the "C.G.S." unit of heat (or lesser calorie). D. 335.

2.* How are "quantities of heat" usually expressed? (D. 322).

3.* How is the temperature of a body usually affected by a change in the number of heat units which it contains?

4. Name certain important exceptions to the rule stated in the last question. Q. LXIV.

5. What relation is assumed to exist between the heat absorbed by a body when it rises through a given range of temperature, and that given out by the body in falling through the same range of temperature? D. 333, (1).

6.† What assumption is universally made as to the constancy of the quantity of heat in the last question?

7. What is meant by the thermal capacity of a body? D. 336.

8.* Illustrate the relation between heat, thermal capacity and temperature by a parallel case in hydrostatics.

9. Explain the construction of an ice-calorimeter. D. 345.

10.‡ Describe one or more experiments (*e.g.* by the fusion of ice) showing that different bodies of the same material have thermal capacities proportional to their weights. (D. 333).

11.‡ Describe one or more experiments (*e.g.* by the fusion of ice) showing that two bodies of the same weight, but of different materials, have, in general, different thermal capacities. L.

12. What, in general, is the relation between the thermal capacity of a body and its rise of temperature due to the addition or subtraction of a given amount of heat? D. 336.

13.‡ Describe one or more experiments showing that equal weights of different liquids, receiving the same amount of heat, are raised unequally in temperature; and that different weights of these liquids may be raised equally in temperature by the same supply of heat. L.

14. Find the relation between the thermal capacity, c, of a body (not suffering a change of state), and the difference between its two temperatures, T and t, before and after the loss (or gain) of q units of heat. D. 336.

LXVII.

SPECIFIC HEAT OF SOLIDS AND LIQUIDS.

1.* Define specific heat. D. 337.

2.* Distinguish specific heat from thermal capacity.

3.† Find the relation between the mass, m, specific heat, s, and thermal capacity, c, of a body. (Prob. D. 337).

4. A copper spiral heated to 100° when immersed in 200 grams of turpentine at 15°, raises the temperature to 25°; and it has the same effect, under precisely similar circumstances, upon 100 grams of water. Find the specific heat of the turpentine referred to the water for the given range of temperature. Prob. Q.

5.† Give some idea of the variation in the specific heat of water at different temperatures.

6. A kilogram of water at 100° is mixed with a kilogram of water at 0°. If the resulting temperature is 50°.2, how does the average specific heat of water between 0° and 50°.2 compare with that between 50°.2 and 100°? Prob. Q.

7.‡ Describe a simple form of experiment testing the uniformity of the specific heat of water as measured by the rise of a mercurial thermometer.

8. Give some idea of the specific heats of ordinary solids and liquids. D. 341.

9. How does the specific heat of water compare with that of most other substances? D. 342.

10. What do you infer from Q. 9 to be the influence of large bodies of water upon climate? Prob.

11. Show in general that water must exert a relatively conservative influence upon changes of temperature. D. 342, 350, 351, 415. Q. LXIV., LXVII.

12. State the law of DULONG and PETIT concerning the relative specific heats of elementary substances. D. 344.

LXVIII.

SPECIFIC HEAT OF GASES.

1.† Distinguish between the two specific heats of a gas at constant pressure and at constant volume.

2.† Which of the two specific heats of a gas is determined in ordinary experiments? (D. 343).

3.† Which specific heat of a gas is understood in the absence of any statement to the contrary?

4. State the effects (if any) of temperature and pressure on the specific heat of a perfect gas. D. 334, 343.

5.† How does the absolute temperature of a gas compare with the total amount of heat which the gas is supposed to have received?

6.† Give some idea of the specific heats of common gases.

7. How do different gases compare as to the thermal capacity of (1) a given mass and (2) a given volume? D. 343.

8.† Find the thermal capacity of a cubic centimetre of air, oxygen, nitrogen, hydrogen, etc., at 0° and 76 cm. pressure. (Prob. D. 329, 343).

9. Show that the specific heat of a molecule of each of the gases in the last question must be a nearly constant quantity. Prob. Q. XLVII., LXVII., 5. (D. 344).

10.† State in general the dependence of the specific heat of a molecule upon the complexity of its structure.

11.† Explain the last question on the supposition that the pressure of a gas is due to molecular vibration (Q. XLIX.), while the specific heat of a gas is due to the absorption of energy both in molecular vibration and in atomic vibrations within the molecule.

12.† Correct Deschanel's use (D. 344) of the terms "atom" and "atomic weight" in the application to gases of the law of DULONG and PETIT.

(See farther LXIX., 25, and LXXII., 1-7).

LXIX.

METHOD OF MIXTURES.

1. What is meant by the method of mixtures? D. 338.

2. If m_1 grams of a given substance at the temperature, t_1, and m_2 grams of water at the temperature, t_2, come into thermal equilibrium at the temperature, t, what is the specific heat of the substance in question? D. 339.

3.‡ Explain the construction and use of an ordinary calorimeter, with inner and outer cups.

4. Describe Regnault's apparatus for the determination of specific heat, and state some of its advantages. D. 341.

5.† Under what circumstances are the effects of the thermal capacity of a calorimeter eliminated?

6.† Does the thermal capacity of the inner and outer cup, or that of the inner cup alone affect results obtained with a calorimeter, and why?

7.† Calculate the thermal capacity of a calorimeter having an inner cup composed of a mass, m, of material having the specific heat, s. Q. LXVII., 3.

8.† 90 grams of water at 0° are introduced into a calorimeter previously heated to 100°, and thermal equilibrium is obtained at 10°; find the thermal capacity of the calorimeter.

9.† Why is the use of felt, or other insulating substance of considerable thermal capacity, avoided in modern calorimeters?

10. How are the thermal capacities of the thermometer, stirrer, calorimeter, etc., allowed for in ordinary determinations of specific heat by the method of mixtures? D. 340, I.

11.† What assumption is made as to the algebraic sum of the quantities of heat given out or absorbed by the different bodies concerned in calorimetry?

12. Several bodies of the masses, m_1, m_2, m_3, etc., and specific heats, s_1, s_2, s_3, etc., at the temperatures, t_1, t_2, t_3, etc., respectively, come into thermal equilibrium at the temperature, t; find an equation expressing the relation between the heats given out or absorbed. D. 338.

13. A calorimeter having a thermal capacity (or water equivalent) equal to that of 10 grams of water, and containing 90 grams of water at 5° Centigrade, is raised to 35° by the immersion of 2000 grams of lead shot, previously heated to 85°. Find the specific heat of the lead shot. Prob. Q.

14. If 180 grams of turpentine can be substituted in the last question for 90 grams of water without changing the result, what is the specific heat of the turpentine? Prob. Q.

15.† Explain the determination of the specific heat of a liquid by the method of mixtures, making use of a solid of known specific heat.

16. Explain the use of an envelope in the determination of specific heats of liquids which mix with water. D. 341.

17. How is the latent heat of liquefaction of water determined by means of a calorimeter? D. 350.

18. 10 grams of ice form a mixture at 20° with 90 grams of water at 30° contained in a calorimeter of 10 units thermal capacity; find the latent heat of the water. Prob. Q.

19.† Explain the determination of the latent heat of steam by means of a calorimeter.

20.‡ Describe the construction and use of a steam trap in connection with the determination of the latent heat of steam.

21. Describe Despretz's apparatus for the determination of the latent heat of vaporization of liquids in general, and state the advantages of the "worm" which he employed. D. 414.

22. 10 grams of steam form a mixture at 37° with 200 grams of water at 7°; find the latent heat of the steam. Prob. Q.

23. Two grams of zinc dissolving in a solution of sulphuric and chromic acids having a specific heat of .9 and weighing 100 grams, raise this solution, and the glass calorimeter of 10 units thermal capacity containing the solution, from 0° to 36°. Find the heat of combination of the zinc with the solution in question. Prob. Q.

24. One kilogram of ordinary coal, burning in a combustion-chamber, under water, heats the equivalent of 100 kilograms of water 50 degrees. Find the heat of combustion of the coal. Prob. Q.

25. How are the specific heats of gases at constant pressure usually determined? D. 343.

26. By what device are the effects of cooling sometimes eliminated in calorimetry? D. 340, II.

LXX.

FLOW OF HEAT.

1. State NEWTON's law of cooling. D. 461.

2.† What is the influence of the thermal capacity of a body, and of the area of its surface exposed, upon its rate of cooling?

3. Explain the comparison of specific heats by the "method of cooling." D. 346.

4.* Give names to, and distinguish between, the three different processes by which heat is carried from one place to another. D. 317, 439, 452, 457.

5.‡ Describe one or more experiments illustrating the conduction of heat by solids. D. 439, 445, 446, 449.

6.† State the laws connecting the flow of heat with the length of the conductor, with its area of cross-section, with the difference of temperature between its terminals, and with its specific conductivity.

7.† Show that the specific conductivity of a rod of given section is proportional to the square of the distance between points on the rod which differ, owing to cooling in the air, by a given range of temperature.

8.‡ Describe an experiment (due to Ingenhousz) illustrating the comparative conductivity of different solids. D. 444.

9.‡ Describe the experimental determination of heat conductivity, either as performed in the laboratory (by the fusion of ice), or as described in Deschanel. D. 449; L.

10.† A rod with area of cross-section, a, has permanent temperatures, T and t, at points separated by the distance, d; and it conducts heat enough to melt a mass, m, of ice, of latent heat, L, in the interval of time, i. Find the amount of heat, k, which would be conducted between the two opposite faces of a unit cube of the same material, if a unit difference of temperature were to be maintained between these faces. (D. 442).

11. Define the "C. G. S." coefficient of absolute conductivity. D. 442; Q. 10.

12. Give some idea of the absolute conductivity of one or more metals. D. 449, 450.

13.† Give some idea of the absolute conductivity of non-metallic solids.

14.* How do metals compare with non-metallic substances as conductors of heat? D. 445.

15.*†Why do metals feel colder than non-metallic substances at ordinary temperatures? And how is this comparison modified at the temperature of an oven?

16. Describe one or more experiments on the conductivity of water. D. 453, 454.

17.† Give some idea of the conducting power of (non-metallic) liquids.

18.* How do gases compare with solids and liquids as conductors of heat? D. 455.

19.† Give some idea of the absolute conductivities of gases.

20.† Upon what well-known constant does the relative conductivity of a gas or vapor depend?

21.† Criticise Deschanel's statement (D. 456) implying that the *vapor* of a metal shonld conduct heat better than the *vapor* of a non-metallic substance.

22.† Show that thermal conductivity is closely connected with diffusion and with viscosity in liquids and gases.

23.† Explain the origin and meaning of the term "diffusivity" as applied to heat in the sense of "conductivity of temperature." D. 441, 442.

24. Distinguish between diffusivity (or conductivity of temperature) and thermal conductivity. D. 449-451.

25. Express rate of diffusivity, r, in terms of thermal conductivity, k, density, d, and specific heat, s. D. 442, (3).

26.‡ Describe an experiment illustrating the comparative diffusivity of different metals (as distinguished from their comparative thermal conductivity). D. 444; L.

27.‡ Describe one or more experiments showing that heat is carried in bodies of water by convection much more freely than by conduction.

28. Give instances of heating by convection. D. 317, 318, 550, 551.

29.* Why do we heat vessels of liquid from below?

30.‡ Describe one or more experiments illustrating the superiority of hydrogen over other gases for carrying heat. D. 445.

31.† Do the experiments cited in the last question prove that hydrogen is a superior *conductor* of heat (as stated in D. 455), or may the phenomena be interpreted as the results of superior *convection*?

32.* How do you explain the small thermal conductivity of powders, woolen stuffs, or any finely divided substance?

33.† Give some idea of the conductivity of different finely divided materials.

34. Describe various devices for the insulation of heat, (*i.e.*, for preventing it from flowing in or out of an enclosure). D. 447, 448.

35.† To what branch of Physics does the "radiation" of heat properly belong?

(For questions on the radiation of heat, see under Light).

LXXI.

MECHANICAL EQUIVALENT OF HEAT.

1.‡ Describe one or more experiments illustrating the fact that heat is produced by the compression of air. D. 484.

2.* Describe one or more experiments illustrating the production of heat by friction. D. 485.

3. Describe an experiment showing that work done against magnetic forces may be transformed into heat. D. 486.

4.‡ Describe an experiment in which lead shot is heated by a definite amount in falling, under the action of gravity, through a measured distance. L.

5.† One kilogram of shot, in falling through a distance of one metre a hundred times in succession, is heated about 7 degrees; find the height that one gram must fall to be heated one degree; and the work in gram-centimetres done by gravity upon this gram during the fall. Prob.

6.† If the specific heat of the lead shot in the last question is 0.032, what is the distance through which a gram of water must fall in order that it may be heated one degree? and what is the value in gram-centimetres of the work necessary to heat one gram of water one degree Centigrade? Prob. Q.

7.† What name is given to the quantity of work named in Q. 6?

8. Define the "mechanical equivalent of heat." Q.

9. What is the relation between any quantity of heat, H, (expressed in gram-degrees), the corresponding amount of work, W, (in gram-centimetres), and the "mechanical equivalent of heat," J, (expressed in gram-centimetres per gram-degree)? D. 488.

10.† Express the results in Q. 5-9 in ergs instead of gram-centimetres (see Q. V. 5, XXVII., 4).

11. Describe Joule's determination of the mechanical equivalent of heat. D. 487.

12.† State Joule's value for the mechanical equivalent of one unit of heat (1) in gram-centimetres of work and (2) in ergs.

13.† Give some idea of the mechanical equivalent of different sources of heat.

14. Find the equivalent in watts of one unit of heat per second. Q. XXXIII., LXXI., 12.

15. Find the heating power to be derived from one watt. Q.

16. State the "first law of thermodynamics." D. 488.

LXXII.

CONVERSION OF HEAT INTO WORK.

1. Describe an experiment (due to Joule) showing that when a gas expands without doing work against its enclosure, its average temperature remains constant. D. 489.

2.† Why does a gas become cooler when it is allowed to expand, and warmer when it is forced to contract, under ordinary circumstances? (D. 489).

3. Show that the heat required to effect a given change of volume and temperature depends upon the course by which this change is effected. D. 497.

4. Explain the existence of a difference between the two specific heats of a gas at constant pressure and at constant volume. D. 489.

5.† Let d be the density of air at zero and at the pressure, p; let e be its coefficient of expansion, s its specific heat *at constant volume*; and let J be the mechanical equivalent of one unit of heat. Find (1) the thermal capacity, at *constant volume*, of one cu. cm. of air; (2) the expansion and (3) the work done by a cu. cm. of air when raised from 0° to 1° Centigrade; (4) the heat equivalent of this work; (5) the thermal capacity of the cu. cm. of air at *constant pressure*; and (6) the specific heat of air at *constant pressure*. (D. 490).

6. Substitute in the last question, .001293 for d, .169 for s, .00367 for e, 1033 grams per sq. cm. for p, 42,500 gram-cm. per gram-degree for J. Prob. Q.

7. Find in the last question the ratio of the specific heat of air at constant pressure to that at constant volume. D. 400. Prob. Q.

8.† In what class of gases, alone, is the ratio of the two specific heats equal to 1.408, nearly?

9.† Show that the *difference* between the two thermal capacities of the unit of volume of a gas depends only upon the pressure and coefficient of expansion, and is accordingly the same for all gases at a given pressure having the same coefficient of expansion. (Prob. Q.)

10. What in general is meant by a heat (or thermic) engine? D. 491, 516.

11. Define the efficiency of a heat-engine. D. 491.

12. If T' is the lower and T'' the higher temperature (on the absolute scale) available in a heat engine, what is the maximum efficiency which such an engine can possess? D. 494.

13. State the "second law of thermodynamics." D. 494.

14. Name some available sources of energy. D. 514.

15. What is meant by the "dissipation of energy?" D. 515.

END OF PART II.

QUESTIONS ON GENERAL PHYSICS.

PART III.—ELECTRICITY AND MAGNETISM.

LXXIII.

ELECTRICAL ATTRACTIONS AND REPULSIONS.

1. What facts concerning electricity were known to the ancients?

2. What is the derivation of the word electricity? D. 556.

3. What is meant by electricity, or by electrification? D. 556.

4.† What is meant by a charge of electricity? (D. 559; 562; 565, ¶3; 579).

5.‡ Describe one or more experiments showing that the action of different electrified bodies upon a pith-ball, charged in a given manner, is not the same.

6.‡ Describe one or more experiments showing that the action of a body electrified in a given manner, upon a pith-ball, electrified in different ways, is not the same.

7.* Into how many and what classes can all electrified bodies be divided with respect to their mutual action at a distance? D. 559.

8.* Define vitreous, resinous, positive, and negative electricity. D. 558.

9. Give a list of several substances, each of which becomes positively electrified if rubbed with one below it in the list, but negatively electrified if rubbed with one above it in the list. D. 560.

10.‡ Describe one or more experiments illustrating the facts represented by a list constructed as in the last question.

11.* What force is exerted (1) by a body electrified vitreously (*a*) upon one vitreously and (*b*) upon one resinously electrified; also (2) by a body resinously electrified upon (*a*) one vitreously and (*b*) upon one resinously electrified? D. 559.

12.* What is the mutual action between (1) two similar charges? (2) between two dissimilar charges? D. 559.

13.‡ Describe an experiment showing that dissimilar charges are produced in two bodies, when rubbed together. D. 560.

14.‡ Describe one or more experiments showing that equal, as well as opposite, charges are produced in two bodies when rubbed together.

15.* Explain what happens when a pith-ball is touched to an electrified body, and then subjected to the action of its electric forces from a distance. D. 558.

16.* Explain the electrostatic vibrating bell. D. 647.

17. Describe the construction and use of a Coulomb's torsion balance. D. 566.

18. State the law for the repulsion, f, of two similar charges, q' and q'', at the distance, d. D. 567, 570.

19. Define the electrostatic unit of quantity.

20.† What is meant by an electrostatic field of force?

21.† Express the electrostatic field, F, in term of the force, f, experienced by the quantity of electricity, q.

22. Find the field, F, due to a charge, q, at the distance, d. Q. 18, 21.

LXXIV.

ELECTROSTATIC POTENTIAL.

1.* What in electrostatics corresponds (1) to pressure in hydraulics and (2) to temperature in thermodynamics?

2.† What name is given to the work necessary to bring a unit quantity of positive electricity from an infinite distance to a given point?

3. Define electrostatic potential. Q.

4.† Find the work, w, necessary to bring q units of electricity from an infinite distance up to a point at the potential, W.

5. Find the work, w, necessary to bring q units of electricity from a point at the potential, W', to one at the potential, W''. Prob. Q.

6. If q units of electricity are moved from P' to P'' against a mean force, f, what is the difference between the potentials of P' and P''? Prob. Q. XXVII.; LXXIV.

7. Find the difference of potential between two neighboring points, P' and P'', at the nearly equal distances, d' and d'', from a quantity, q, of positive electricity. Prob. Q. LXXIII., LXXIV.

8.† Show that the potential of a point at the distance, d, from a charge, q, may be represented by the quotient, q/d.

9. Express the electrostatic field, F, between two neighboring points, P' and P'', in terms of the (difference between the) potentials, W' and W'', of these points. Prob. Q. LXXIII., LXXIV.

10. Find the force, f, urging q units of electricity between two points, P' and P'', at the potentials, W' and W''. D. 602; Q.

11.† Show that electrical charges tend to move from places of high to places of low potential.

12.† When are two bodies said to have the same potential? (D. 605).

13. What is meant by an equipotential surface? D. 604.

14. When is a region of space said to have the same (uniform) potential throughout? D. 605.

15. What name is given to an instrument serving to indicate differences of electrostatic potential? D. 640.

16.‡ Describe and explain the use of a pair of pith-balls as an electrometer.

17.‡ Describe one or more experiments with a pith-ball electrometer showing that the potential WITHIN a closed metallic surface (uniformly) charged with electricity, is uniform. (D. 574).

LXXV.

CONDUCTORS AND NON-CONDUCTORS.

1.† Explain what happens when an electrified and an unelectrified body are brought into contact.

2.* Is it necessary that two bodies be brought into contact in order that their electrifications may be equalized?

3.* Distinguish between conductors and non-conductors, or insulators. D. 557.

4.* Why cannot metals be electrified without special precautions? D. 556.

5.† Describe an experiment showing that metals can be electrified. D. 556.

6.‡ Describe one or more experiments showing that (1) metals are good conductors of electricity, that (2) wood, marble, etc., are poor conductors; cotton, wool, etc., poor insulators, and silk, resin, etc., good insulators.

7.† What is true of the order of electrical conductivity as compared with that of thermal conductivity? D. 744.

LXXVI.

DISTRIBUTION OF ELECTRICITY ON THE SURFACES OF CONDUCTORS.

1.† Prove that no force is exerted by a hollow electrified spherical shell upon an electrified body within it.

2.† Show that no electricity will be imparted by a hollow electrified shell to an unelectrified body within it.

3.‡ Describe and explain Biot's experiment (with sphere and pair of hemispherical covers).

4.‡ Describe and explain one or more experiments with a hollow sphere and a proof plane. D. 571.

5. Show that certain qualitative experiments afford a complete confirmation of the law of inverse squares as applied to electrostatic repulsion. D. 574; Q. LXXIV., 17; LXXVI.

6. What is meant by electrical density? D. 575.

7. In what portions of an irregular conducting surface is the electrical density greatest? and in what portions is it least? D. 575, 578.

LXXVII.

ELECTROSTATIC INDUCTION.

1. What happens when a body positively charged is brought near one end of a long conductor? D. 563.

2. What is the sign of the electrification of a conductor (1) at the end nearer a positive charge of electricity and (2) at the farther end? D. 563.

3.‡ Describe one or more experiments illustrating electrostatic induction. D. 563.

4. Explain the attraction between an electrified and an unelectrified body. D. 564.

5.* Is attraction or repulsion a more reliable test of the sign of a charge, and why? D. 564.

6. What happens when a conductor, electrified by induction, is "grounded," (that is, connected by a conducting channel with the ground)? D. 563.

7. Describe a gold-leaf electroscope. D. 565.

8.‡ What happens when an electrified body is held above the leaves of a gold-leaf electroscope? When in this condition of things, the knob of the electroscope is touched with the finger? When the finger is removed? And when subsequently the electrified body is withdrawn? D. 565.

9.‡ State how (if at all) the results in the last question would be modified if, instead of holding the electrified body above the knob of the electroscope, it were to be held within a pail, or other metallic enclosure, connected by a conductor with the electroscope, but insulated from the ground. D. 573.

10. Explain the "ice-pail" experiment by principles previously worked out. Q.

11.† Distinguish a free from a bound charge.

LXXVIII.

ELECTROSTATIC INDUCTION MACHINES.

1.* Describe an electrophorus. D. 586.

2.† Name the sign of the charge given by a catskin to the ebonite of an electrophorus.

3. Name the sign of the charge induced in the cover of an electrophorus charged as in the last question. D. 586.

4. Should the cover be grounded while in contact? and why? D. 586.

5. What is the use of the screw-heads passing through the ebonite disc? D. 586.

6.† Give reasons why the dissimilar charges of electricity do not unite by jumping across the small distance between the ebonite and the cover.

7.‡ How does the length of spark obtainable from the cover after it is raised compare with that obtainable when in place?

8. What happens when the cover is raised as concerns (1) the quantity of the charge which it contains and (2) the potential of this charge? D. 586.

9.† How do you account for the fact that while the difference of potential between the inducing and the induced charges is not sufficient to cause a spark (say one 32d of an inch in length), this difference of potential becomes sufficient to give rise to a spark (at least an inch long) when the cover is separated from the ebonite?

10.† Name the source of energy giving rise to the almost indefinite series of sparks which can be derived from an electrophorus without re-charging it.

11. Describe the Holtz-Voss machine. D. 588.

12. Calling the electrification of the left-hand paper positive, and that of the right-hand paper negative, state the sign of the following charges, and whether they are free or bound in each case :

(1) On the button between the equalizer and the positive paper ;

(2) On the button just beyond the above ;

(3) On the button opposite the replenisher of the negative paper ;

(4) On the button between the negative paper and the teeth of the pole ;

(5) On the teeth of the pole ;

(6) On each pole. Prob. D. 588.

LXXIX.

CONDENSERS.

1.* What is meant by a condenser? D. 616.

2.‡ Describe an experiment showing the effect upon the free charges on the plates of a condenser due to approach or recession of these plates. D. 624, Fig. 386.

3.† What is meant by the capacity of a condenser?

4.† Express the capacity, C, of a condenser, in terms of the quantity, q, of positive or of negative electricity in each plate, and the difference of potential, W, of these plates. (D. 617).

5.† Show that the capacity of a condenser is inversely proportional to the distance between the two plates. (D. 617, Prob. Q.).

6.‡ Describe and explain one or more experiments illustrating effects of nearness of the plates of a condenser on the loudness and frequency of the spark across a given distance.

7. Explain the shock experienced by Cuneus. D. 619.

8. Describe a Leyden jar—a Leyden battery. D. 620 and 630.

9. What is meant by a residual charge? D. 621.

10.‡ Describe one or more experiments with a jar with movable coatings, and state what is proved by these experiments. D. 622.

11. What happens when one plate (only) of a condenser is earthed? D. 622.

12. Aside from considerations of residual charge, why cannot a condenser be completely discharged by earthing first one pole, then the other? D. 622.

13.‡ Describe an experiment with pith-balls illustrating the point in the last question. D. 622, Fig. 384.

14.‡ Describe one or more experiments illustrating the effect of introducing a piece of glass between the plates of a condenser. D. 624.

15. What is meant by specific inductive capacity? D. 624.

16.‡ How does a list of substances in order of their specific inductive capacity compare with one in the order of their respective indices of refraction?

LXXX.

DISRUPTIVE ELECTRICAL DISCHARGE.

1. State some facts concerning the dissipation of electrical charges. D. 579.

2. Describe one or more experiments (due to Lichtenberg) indicating that positive electricity travels more rapidly than negative electricity over certain surfaces. D. 631.

3. Are positive or negative charges more rapidly dissipated by the air? D. 579.

4.‡ Describe one or more experiments illustrating the formation of wind from electrified points. D. 598, 651.

5. What is meant by an electric "brush?" D. 590.

6.‡ Distinguish the appearance of a positive from that of a negative brush. D. 590.

7.† What does Deschanel mean in speaking of the electric brush as a case of continuous discharge (D. 590) and in what does it really consist? D. 591.

8. Give some idea of the duration of the electric spark. D. 591.

9. Give some idea of the velocity with which an electric spark may be transmitted by a wire. D. 636

10. Describe some of the physiological effects of the electric spark. D. 595.

11.† Give some idea of the differences of potential causing sparks to jump through air between smooth surfaces separated by different distances.

12.‡ What is meant by the multiplication of the electric spark? D. 594.

13.‡ Describe the luminous appearances of sparks transmitted through one or more rarefied gases or vapors. D. 592, 817.

14.‡ Describe one or more experiments illustrating the volatilization of solids or liquids by the electric sprrk. D. 593, 635.

15. Upon what circumstances does the color of an electric spark depend? D. 593.

16.‡ How may ignition be produced by a spark? D. 596, 639.

17.‡ Describe one or more experiments illustrating the heating power of an electric spark. D. 596, 638.

18. Explain the phenomena of Q. 13, 14, 15 and 16 as the result of heating effects. D. 596.

19.‡ How may puncture be produced by means of a spark? D. 638.

20.‡ Describe one or more experiments illustrating the disruptive effects of an electric spark. D. 596, ¶4; 634.

21.† Explain the various disruptive effects of an electric spark as the result of electrostatic forces combined with heating.

22.† Describe the sound produced by an electric spark, and state how this may be explained.

23. Describe one or more experiments illustrating chemical effects of the electric spark. D. 597.

24.‡ Describe one or more experiments showing that steel can be magnetized or demagnetized by an electric spark.

25.† Explain the somewhat fortuitous results of the experiments in Q. 24 on the supposition that electric discharges are oscillatory.

26.† Show that all the physical effects of an electric spark may be classed as (1) electrostatic, (2) thermal, (3) chemical, or (4) magnetic.

LXXXI.

IDENTITY OF ELECTRICITY FROM DIFFERENT SOURCES.

1. What class of machines produce electricity by means of electrostatic action? Q. LXXVIII.

2.‡ Describe one or more experiments showing that electrostatic effects may be exhibited by electricity of thermal (thermo-electric or pyro-electric), chemical (voltaic), or magnetic (magneto-electric), as well as electrostatic origin.

3.‡ Describe one or more experiments showing that thermal effects are exhibited by electricity, regardless of its origin, when caused to flow through a conductor.

4.‡ Describe one or more experiments showing that chemical action may be produced by electricity of thermal, chemical, or magnetic, as well as electrostatic origin.

5.‡ Describe one or more experiments showing that a flow of electricity, from whatever source, is capable of deflecting a magnetic needle.

6. State some of the evidence leading to the inference that the electricity derived from various sources is identical in kind. Q.

7. Classify the sources of electricity which you have met with under four heads, corresponding to the four kinds of effect which you have seen that electricity can produce. Prob. Q. LXXX., LXXXI.

8.† Under what head do you class the electrophorus? the Holtz-Voss machine? the thermo-battery? the voltaic cell? the telephone used as a transmitter? magneto-electric machines? the dynamo? (Prob. Q.)

9.† From what source do we generally derive (1) small quantities of electricity at very high potential? (2) moderate quantities of electricity at considerable potential? (3) the same, or small quantities, at low potential? (4) the same at very low potential?

10.† Give some idea of the number of Holtz-Voss machines which would yield a current of electricity as great as that due to a voltaic cell.

11.† Give some idea of the number of voltaic cells which would be necessary to produce a spark as long as that of a Holtz-Voss machine.

12.† What kind of electricity (vitreous and positive or resinous and negative) is derived from (1) the copper or carbon and (2) the zinc pole of an ordinary voltaic cell?

LXXXII.

MUTUAL ACTION OF CURRENTS.

1. State Ampères theory of the constitution of a magnet. D. 794.

2. Upon what fundamental hypothesis did Ampère explain the action of currents on magnets? D. 788.

3. Describe one or more experiments indicating that two parallel currents attract, and two currents in opposite directions repel each other. D. 782, II.

4.† Explain why two parallel coaxal coils attract each other if the current circulates in the same direction in both, but repel each other if the current circulates in opposite directions. (Q.)

5.‡ Describe one or more experiments (depending upon the division of a current) showing that the attraction or repulsion between two coils depends upon the product of the currents through each.

6.‡ Describe one or more experiments showing that the attraction or repulsion between two coils is proportional to the product of the lengths of wire in each, when the current through each and distance between the wires remains the same.

7.‡ Describe one or more experiments showing that the attraction or repulsion between two coils varies inversely as the square of the distance between their wires, the total length of wire and the current remaining the same.

8. State the laws connecting the attraction or repulsion between two coils (1) with the strength of the current in each, (2) the length of wire in each, and (3) the distance between the two coils. Q.

9.† Find the position of equilibrium of two coils in the same plane (1) one inside of the other and (2) each outside of the other. (Prob. Q.)

10. Explain the orientation of coils of wire, free to move while transmitting electric currents, upon the supposition that electric currents exist in the earth, beneath them. Q. 9.

11.‡ Describe one or more experiments illustrating the orientation of coils of wire under the action of (supposed) earth-currents. D. 789, 790.

12.† How can you find the direction of the earth-currents which would account for the phenomena of the last question? and what is this direction?

13. What is meant by a solenoid? D. 790-792.

14.† Which pole of a solenoid is called the north-seeking pole? or the north pole (according to American and general English usage)? D. 669.

15.† In what direction does the electric current appear to circulate (*i.e.* with or against the hands of a watch) as seen by a person facing the north pole of the solenoid? (Q. 12).

16.‡ Describe one or more experiments showing that the resultant action between two solenoids is in all cases (qualitatively at least) the same as if poles, obeying the laws of the repulsion of similars and attraction of dissimilars, were situated one at each end of the solenoid. D. 792.

LXXXIII.

ELECTROMAGNETS.

1. What happens to a piece of soft iron when it is introduced into the interior of a solenoid? D. 796.

2. What is meant by an electromagnet? D. 797.

3. Do the poles of a solenoid correspond with those induced in its soft iron core? Prob. D. 790, 796.

4. How did Ampère explain the creation of an electromagnet? D. 794.

5.† Account for the fact that there is a maximum possible magnetization for a soft iron core, or for any core.

6. What is meant by the keeper or armature of an electromagnet (or any magnet)? D. 794.

7.† About how many pounds can a soft iron core, say 1 inch square, be made to sustain by means of a soft iron armature? (D. 797).

8.† How do cast iron and steel compare with soft iron for the purpose of constructing strong electromagnets? (D. 670).

9.† Name some of the most common substances, other than iron or steel, of which the cores of electromagnets can be made; and state how such electromagnets compare in strength with those having soft iron cores.

10.† State whether the substances alluded to in the last question are or are not invariably attracted by electromagnets and *vice versa*.

11. What happens when the current in an electromagnet with a soft iron core is interrupted? D. 797.

12. What is meant by residual magnetism? D. 798.

13.‡ Describe one or more experiments illustrating the existence of residual magnetism in soft iron.

14.‡ Describe one or more experiments illustrating the preservation of magnetism (in soft iron especially) by a keeper or armature.

15. Does steel or soft iron yield the more easily to the influence of feeble magnetic forces, as concerns (1) the creation, (2) the destruction, and (3) the reversal of magnetic properties? D. 670.

16. What is meant by the "coercive force" of steel? D. 670.

17. Should the cores and armatures of electromagnets, if intended to move rapidly in response to the making or breaking of an electric circuit, be made of iron or of steel? Prob. Q.

18. Is contact between the core and armature of an electromagnet desirable when rapid response is required? Prob. Q. 14.

19.‡ Explain the ordinary telegraph instrument, consisting of a Morse sounder and key.

20.‡ Explain the action of a relay.

LXXXIV.

PERMANENT MAGNETS.

1.‡ What change takes place in a piece of steel when introduced into the interior of a coil of wire carrying a powerful current? Is this change temporary, as in the case of iron? or does it continue to exist after the current has ceased? (D. 670).

2. What is meant by permanent magnetism (1) as distinguished from ordinary residual magnetism and (2) as distinguished from induced magnetism? D. 670, 798.

3.*†What is meant by a permanent magnet?

4.† Describe one or more experiments showing that permanent magnets have powers of attracting iron or other magnetic materials similar to those of an electromagnet.

5.† What substances other than steel are capable of forming permanent magnets? and how do the strengths of snch magnets compare with those of steel magnets?

6.‡ Describe one or more experiments with a lodestone. (D. 661).

7.† Give some idea of the limits of strength in steel magnets. (D. 689).

8.† State certain facts showing that the amount of permanent magnetism imparted to a piece of steel may depend somewhat upon the duration of the magnetizing forces.

9.† Give some idea of the amount by which a permanent magnet is likely to become weakened in the course of time.

10.‡ Describe and explain one or more experiments illustrating the permanent magnetization of bars by striking them in a magnetic field too feeble to bring this result about without a blow.

11.† State the general effect of jarring a permanent magnet, especially when its poles are near similar poles of another magnet.

12. Of what material would you construct a permanent horseshoe magnet? How would you magnetize it? and what means would you take to preserve its magnetism? Q.

13.*‡ Describe one or more methods of magnetizing a piece of steel by means of an electromagnet, or by means of a permanent magnet. D. 689.

14.*‡ Describe one or more experiments showing that permanent magnets orient themselves, when free to rotate, like solenoids or electromagnets of the same shape.

15.* What name is given (in this country), in a general sense, to the north-seeking *end* of a magnet? to the south-seeking end? D. 669, Q. LXXXII., 14.

16.‡ Describe one or more experiments illustrating the mutual attractions or repulsions between the poles of a solenoid and those of a magnet.

17.*‡ Describe one or more experiments illustrating the mutual attraction or repulsion of two magnetic poles.

18.* If the earth's action upon suspended magnets is due to a magnetic pole in Labrador, is this a north or a south pole, and why? Q.

19. Compare the statements of the law of similars and dissimilars (1) for two solenoids, (2) for a solenoid and a magnet, and (3) for two magnets. Q.

20. State some of the evidence leading to the inference that a permanent magnet is equivalent to a solenoid. Q.

21.† Point out the bearing of the facts called for in the last question upon Ampère's theory of the constitution of a permanent magnet. (See Q. LXXXII., 1, 2).

22.† What should happen, according to Ampère's theory, when a permanent magnet is broken into fragments?

23.‡ Describe one or more experiments illustrating the point in the last question. D. 671.

LXXXV.

STRENGTH OF POLES AND FIELDS.

1.‡ Describe one or more experiments showing that the forces exerted by a magnet are greatest near the ends. (D. 662).

2. Draw a curve representing the strength of a bar magnet at different points. D. 664.

3.† What is meant by the neutral point on a magnet? Is this necessarily at the middle of the magnet?

4.† What name is given to the centres of the forces emanating from the two ends of a magnet?

5.‡ Describe one or more methods by which the poles of a bar-magnet may be located, and state the general result of such experiments. L.

6.† How does the attraction or repulsion between two magnets, when side by side and close together, compare with that between a single pair of poles, and why?

7. What is the law connecting the attraction or repulsion between two magnetic poles with the distance between them? D. 674.

8. How is the force between two magnetic poles modified by a variation in the strength of either or both poles? D. 674.

9.‡ Describe several experiments illustrating the answers to the last two questions. L.

10. What is the force, f, between two magnetic poles, M and m, at the distance, d? D. 674.

11.‡ Describe one or more methods by which the strength of a magnetic pole may be measured. L.

12. What is meant by the "moment" of a magnet? D. 674.

13.† Define a unit magnetic pole.

14. What is meant by a magnetic field? D. 673, foot-note.

15. Define the strength of a magnetic field in terms of the force experienced by a unit magnetic pole. (Prob. D. 674).

16. Find the force, F, exerted by a pole of the strength, m, upon a unit pole at the distance, d, and state the strength of the magnetic field due to the pole at this distance. Q.

17. Show that the force between two magnetic poles is equal to the product of the strength of either pole, and that of the magnetic field due to the *other pole*. Q.

18.† A magnetic pole of strength, M, is placed in a magnetic field of strength, F, due to any source whatever; how do you find the force, f, which is brought to bear upon the pole? (D. 674).

19. Express the strength of a pole, M, in terms of the force, f, experienced in the field, F. Q.

20. Find the field, F, in which a pole of strength, M, experiences the force, f. Q.

21.‡ Describe one or more methods by which the (horizontal component of the) earth's magnetic field may be determined by means of a magnet with poles of known strength and position. L.

22. What is meant by the "horizontal intensity" of the earth's magnetism? by its "vertical intensity?" by its "total intensity?" D. 678.

23.† Give some idea of the strength of the earth's magnetism in different localities.

24.† Under what circumstances is the earth's magnetism practically constant in different parts of a laboratory?

25. Describe two or more experiments showing that the earth does not exert any force upon a magnet as a whole either in a vertical or in a horizontal direction. D. 677.

26. State evidence that the two poles of a magnet are equal and opposite in strength. Q.

LXXXVI.

MAGNETIC FORCE-LINES.

1.† What is the direction of the force between two magnetic poles with respect to the line joining them?

2. How do you find the resultant of two or more magnetic forces acting upon a given pole? Q. VII., 7.

3.† Explain the construction of a diagram showing the resultant of the forces exerted by the north and south poles of a magnet upon a magnetic pole at different points in their neighborhood. (Prob. Q. VII., 7; LXXXV.)

4.† What relation exists between the resultants in the last question and the direction of the path followed by a pole free to move under the influence of the magnetic forces exerted upon it in each case?

5.‡ Describe one or more experiments illustrating the point in the last question.

6.† Explain the construction of a diagram showing various paths which a pole would follow under the influence of a magnet in its neighborhood.

7.† What name is given to the path of a pole, free to move under magnetic forces?

8.† What are meant by magnetic lines of force? (D. 672).

9. Are the lines of force due to a magnet confined to a single plane? Q. 2, 3.

10.† What is meant by a tube of force? (D. 607).

11.† Find (by inspection of diagrams, Q. 3 and 6) whether an increase in the cross-section of a tube of force is accompanied by an increase or diminution in the magnitude of the force. (D. 607).

12. What general relation exists between the number of tubes of force which cross a given unit of area and the magnitude of the force across the area in question? Q.; D. 608.

13.† Which pole of a magnet is urged in the (so-called) direction of the lines of magnetic force? and how is the other pole urged?

14.‡ Describe the construction of a magnetic needle free to rotate in any plane. D. 667.

15.† State and explain the relation between the direction indicated by the north pole of a magnet, free to rotate in any plane, and that of the lines of magnetic force in its neighborhood.

16.* Describe the construction of a magnetic compass.

17.‡ Describe one or more experiments showing that a compass-needle assumes a direction parallel to that of the (horizontal) lines of force due to a magnet.

18. How can you find the direction of the horizontal component of the lines of magnetic force at any point, by means of a compass-needle? Q.

19.‡ Explain how horizontal lines of force may be traced out with a compass. L.

20.† What is meant by the magnetic meridian of a place?

21. Define magnetic declination, and state how it is determined. D. 666, 680.

22.† Explain some of the uses of a compass in surveying.

23. Describe the construction of a "dipping-needle." D. 681.

24.‡ How can you find the direction of the component of magnetic lines of force in any vertical plane, by means of a dipping-needle?

25.† What is meant by the "magnetic dip" at any place, and in what plane must a dipping-needle be adjusted in order to determine it? Q.

26. Give some idea of the magnetic declination and dip at different points on the earth's surface. D. 684.

27.† What is the direction of the magnetic forces to which a magnetic compass-needle is sensitive under the action of the earth's magnetism?

28.† Explain one or more methods of rendering a compass-needle sensitive to feeble northerly or southerly forces.

29.† How should a dipping-needle be adjusted to detect (1) feeble northerly or southerly forces and (2) feeble vertical forces in the presence of the action of the earth's magnetism?

30.† What position does a magnetic needle take in this locality when free to rotate (1) in a horizontal plane? (2) in a vertical north and south plane? (3) in any plane? (D. 667). Q.

31.† What is meant by an "astatic" combination?

32. Describe the construction and use of an astatic needle. D. 718.

(See farther under Magnetic Induction).

LXXXVII.

MAGNETIC INDUCTION.

1.† State certain points of analogy between electrostatic and magnetic attractions and repulsions.

2.* What happens when a piece of soft iron, or other magnetic material, is brought near a magnetic pole? D. 670.

3. What name is given to the phenomenon in the last question? D. 670.

4.† Point out analogies between magnetic and electrostatic induction.

5.† What is meant by a coefficient of magnetic induction?

6.‡ Describe one or more experiments showing that magnetic induction is intercepted, to a considerable extent, by plates of iron, or other magnetic material.

7. In what respect does iron (or any other magnetic substance) correspond with a conducting material in electrostatic induction? Q.

8.‡ Describe one or more experiments showing that air, glass, paper, wood, and other non-magnetic substances do not interfere with magnetic induction.

9. In what respect do non-magnetic materials correspond with non-conductors in electrostatic induction?

10.* What happens when a rod of iron is removed from the influence of a magnetic pole? D. 670.

11. What in electrostatic induction corresponds with the phenomenon of the last question? Q.

12.† In what respects (if any) are the phenomena of magnetic induction modified if the two ends of the iron rod, subject to this induction, are separated by a small gap?

13.‡ Describe one or more experiments showing that the material filling the gap alluded to in the last question does not affect the result.

14. In what respect do all substances correspond, in their relation to magnetic induction, with conductors in electrostatics? Q.

15.‡ Describe one or more experiments showing that magnetism is not permanently removed from a magnetic pole by contact with iron or any other (magnetic or non-magnetic) material. (D. 670).

16. In what respect do all substances correspond with non-conductors in electrostatic induction? Q.

17.† Show that Ampères hypothesis explains the fundamental phenomena of magnetic induction.

18. Explain, both on theoretical and on experimental grounds, why it is impossible to obtain a charge of north or south magnetism, separate from (an equal charge of) the opposite magnetism. Q.

19. Describe and explain one or more phenomena of successive induction, including the cessation of these phenomena when the cause is removed. D. 670.

20. Distinguish diamagnetic from paramagnetic substances. D. 691, 692, 693.

21.‡ Describe one or more experiments illustrating the peculiar orientation of diamagnetic substances in a magnetic field. D. 693.

22. How is the behavior of diamagnetic substances explained? D. 691, 692.

23.‡ Describe and explain the orientation of paramagnetic substances (not already magnetized) in a magnetic field. D. 691, 692, 693.

24. Describe and explain the manner in which iron filings arrange themselves in a magnetic field. D. 663, Q.

25.† What relation exists between the lines formed by iron filings on a horizontal surface and the direction of the (horizontal component of the) lines of magnetic force along that surface?

26.‡ Describe one or more experiments with a compass-needle illustrating the point in the last question. L.

27.‡ Describe and compare the arrangements of iron filings due to two magnets, one beside the other, but not touching it: (1) with similar poles opposite, and (2) with dissimilar poles opposite; and state in what respects these arrangements are suggestive of the attractive or repulsive forces in play. L.

28.‡ Describe and compare the arrangements of iron filings due (1) to a single pole of a vertical magnet, and (2) to a flat coil of wire. L.

29.‡ Describe and compare the arrangements of iron filings due (1) to a bar magnet, and (2) to a solenoid of the same shape. L.

30.‡ What farther light do the last two questions throw upon the similarity of magnets and solenoids? (See Q. LXXXIV., 20).

31.‡ Describe the arrangement of iron filings on a horizontal surface bisecting a vertical coil of wire traversed by an electric current.

32. What remarkable angular relation exists between the lines of force due to the coil in the last question and those due to a magnet with poles at the points where the coil intersects the horizontal surface? Q. 31.

33. What angle do the lines of force at the centre of a coil carrying an electric current make with the axis of the coil? Q. 31.

34.‡ Describe the shape and relative position of the lines of force due to a single current.

LXXXVIII.

ACTION OF CURRENTS ON MAGNETIC POLES.

1.† State the angular relation between the direction in which a magnetic pole is urged by a current, and the plane containing the pole and the current. (Prob. Q.)

2.‡ Explain the use of the forefinger and thumb to represent (1) the direction of a current, (2) the relative position of a north pole with respect to the current, and (3) the direction in which the north pole is urged by the current, and state which of these three elements is identical with the so-called "electro-magnetic lines of force."

3. Show how any one of the three elements mentioned in the last question may be found if the other two are given. Prob. Q.

4.† Why are we unable to test the direction of the force exerted by a current upon a pole which is opposite one end of the current?

5. State (when it is known) the direction in which a northerly, a southerly, an easterly, a westerly, an ascending, or a descending current acts upon north poles above, below, east, west, north and south of it. Prob. Q.

6. State (when it is known) the direction in which a current from right to left, from left to right, from head to foot, from feet to head, an approaching current, and a receding current act upon north poles above, below, at the right of, at the left of, in front of, and behind each of the currents mentioned, as seen by the observer. Prob. Q.

7. Explain Ampères rule (for the case of a man swimming with the current and facing the north pole of a compass). D. 710; Q.

ACTION OF CURRENTS ON MAGNETIC POLES.

8.† Trace the path of a north pole, free to move under the influence of a current, and compare the result with the lines of iron filings in Q. LXXXVII., 34.

9. Compare the relation between the directions of progression and rotation in a right-handed cork-screw with that between the direction of a current and the direction in which a north pole tends to rotate about it. Q.

10.‡ Describe one or more experiments illustrating the continuous rotation of a pole about a current, and explain this by the principles of preceding questions.

11. A current circulates in a coil with the hands of a watch, as seen by an observer: find the action of various parts of this current on a north pole at the centre of the watch, and the direction of the resultant action of the circuit as a whole. Prob. Q.

12.† How does the direction in which the south pole of a magnet is urged by a current compare with that in which the north pole is urged by the same current?

LXXXIX.

ACTION OF CURRENTS ON MAGNETIC NEEDLES.

1. State the result of substituting the direction indicated by the north pole of a small magnetic needle, free to rotate in any plane, for that in which a north pole is urged by a current in Q. LXXXVIII., 1–7. See Q. LXXXVI., 14; 15.

2.‡ Describe one or more experiments showing that the direction indicated by the north pole of a magnetic needle, under the influence of a current, coincides with the lines of force due to the current, as indicated by iron filings or otherwise.

3. How would you tell, by means of a compass, which way the current is flowing (1) through a vertical wire, or (2) through a north and south wire? Prob. Q.

4. How would you ascertain, by means of a dipping needle, the direction of a current through any horizontal wire? Prob. Q.

5. Find the direction of earth-currents which would account for the orientation of magnetic needles, and compare this with your answer to Q. LXXXII., 12. Prob. Q.

6. A current circulates in a rectangular coil in a vertical plane: find the action of each side of the coil on a needle at the centre of the coil, if the current through the upper side is (1) northerly, (2) easterly, (3) southerly, and (4) westerly; consider whether these actions are in the same or in opposite directions, and state the direction of their resultant. Prob. Q.

7. How should a galvanometer (consisting of a coil of wire with a compass at its centre) be set up in order that it may be sensitive to feeble currents? Prob. Q.

8. Which pole of a magnetic needle is deflected toward that side of a coil from which the current seems to circulate with the hands of a watch? Prob. Q.

9. State the effect of increasing the current through a coil of wire upon the strength of the magnetic field at the centre of the wire. D. 721.

ACTION OF CURRENTS ON MAGNETIC NEEDLES.

10. State the effect of increasing the length of wire in a coil, without change of radius or current, upon the electromagnetic field at the centre of the coil. D. 721.

11. State the effect of increasing the radius of a coil of constant length, upon the field of magnetic force at its centre. D. 721.

12. Find the field of force, F, at the centre of a coil of length, L, and radius, R, due to the current, C, measured in absolute units (C. G. S.). D. 721.

13.† Define the "absolute unit of current" (C. G. S.) by means of its electromagnetic effect.

14.† Define the "ampère" in terms of the absolute unit of current.

15. A current, circulating through a coil of wire in the plane of the magnetic meridian, produces a field of force, F, such as to deflect a magnetic needle, at the centre of the coil, through the angle, A, against the horizontal component, H, of the earth's magnetic field: express F/H as a function of A. D. 715.

16. Explain the construction, adjustment and use of a tangent galvanometer. D. 715.

17. Find the current, c, in absolute units (or the current, C in ampères) which, in passing through a coil of wire of length, L, and mean radius, R, adjusted as in Q. 16, is capable of deflecting a magnet at the centre of the coil through the angle, A, against the horizontal component, H, of the earth's magnetic field. Prob. Q.

18. State some of the advantages of galvanometers with astatic needles. D. 718.

19.† Describe one or more forms of mirror galvanometer, and their advantages when used in connection with a telescope and scale.

20. Describe the construction and use of a Thomson's mirror galvanometer. D. 719.

XC.

ACTION OF MAGNETIC FIELDS ON RECTILINEAR CURRENTS.

1.† What general principle suggests to you, when the direction in which a current acts upon a magnet is given, where to look for the direction in which the magnet acts upon the current? (D. 712).

2. In what direction (if in any) is a northerly, an easterly, a southerly, a westerly, an ascending, or a descending current urged by a north pole above it, below it, north of it, east of it, south of it, or west of it? Prob. Q.

3. In what direction (if in any) as seen by the observer, is an approaching current, a receding current, a current from head to foot, a current from feet to head, a current from right to left, or a current from left to right urged by a north pole above it, below it, at the right of it, at the left of it, in front of it, or behind it? Prob. Q.

4. In what direction would a current represented in direction by the forefinger of the right hand be urged by a magnetic north pole in the position of the thumb, when laid across the forefinger as in Q. LXXXVIII., 2? Prob. Q.

5. State the result of substituting, in the last question, a south pole for the north pole, if the south pole is located on the opposite side of the current. Prob. Q.

6.† State the result of substituting, for either of the poles in Q 4 and 5, a magnetic field with force-lines in the direction of pressure exerted by the thumb upon the forefinger, and explain the extended use of the forefinger and thumb to represent the magnetic (not the electromagnetic) lines of force concerned in the action in question.

7. State in general the angular relation which exists between the *component* strengths of (1) the current, (2) the current's field, and (3) the magnet's field, which determine the mutual action between a current and a magnet, and how (if at all) the other components act upon one another. D. 712, Q.

8. Find the direction (if any) of the lines of force which urge a northerly, southerly, easterly, westerly, upward, or downward current up, down, north, south, east, or west. Prob. Q.

9. Find the direction (if any) as seen by the observer, of the lines of force which acting upon a current flowing from his head to his foot, from his feet to his head, from right to left, from left to right, toward him, or away from him, would urge this current in each of the six relative directions named. Prob. Q.

10. Why are north and south currents unacted upon by the horizontal component of the earth's magnetism? and why are currents, in no matter what direction they flow, never urged north or south by this horizontal component? Prob. D. 712, Q.

11. Show that horizontal lines of force, only, can act upon a vertical current in any direction, or upon any current in a vertical direction. Prob. Q.

12. Show that vertical lines of force, only, can act upon horizontal currents in horizontal directions. Prob. Q.

13.† Given that magnetic and electromagnetic fields are equivalent as far as their action upon magnets is concerned, what farther assumption is necessary in order to explain their action on currents?

14.‡ Describe and explain by the foregoing principles one or more experiments illustrating the continuous rotation of currents in electromagnetic fields. D. 783, 784.

15. Two parallel descending currents pass, one through a point, A; the other through a point, B, south of A. Find the direction of the lines of electromagnetic force at B due to the current through A; and the direction in which the current through B is urged by the lines of force in question. Prob. Q.

16. Show that the rules adopted for determining the direction of electromagnetic lines of force, and for the action of electromagnetic fields upon currents, are consistent with fundamental facts concerning the mutual action of parallel currents. Prob. Q.

XCI.

ACTION OF MAGNETIC FIELDS ON CLOSED CIRCUITS.

1. A current, C, circulates through a coil of length, L, and radius, R; find (1) the electromagnetic field of force, F, (Q. LXXXIX., 12), and (2) the force, f, experienced by a magnetic pole of strength, M, at the centre of the coil (Q. LXXXV., 18): find also, by the principle of action and reaction (Q. XC., 1) the magnitude of (3) the force, f'', exerted by the pole upon the circuit; and (4) the strength of the field of force, F'', due to the magnetic pole at the distance, R, (Q. LXXXV., 16) by which this action upon the circuit is produced. Prob. Q.

2. Find the force, f, experienced by a wire of length, L, transmitting a current, C, at right-angles with the lines of force of a magnetic field, F. Q. 1.

3. A current, C, flows through a rectangle with horizontal sides, A and B, and vertical sides, C and D, C being north of D: find the force exerted by the horizontal component, H, of the earth's magnetism upon each of these sides, and specify the nature, sign, and magnitude of the joint action of the four forces. Prob. Q.

4. How would the results in the last question be modified if, instead of the rectangle of wire, there were to be substituted a rectangular coil containing N turns of the same dimensions? Q.

5.† What is meant by the "magnetic area" of a coil, and what influence does this have in determining the magnitude of the couple brought to bear upon it in a magnetic field?

6.† Find the couple exerted by the component, F, of a magnetic field in the plane of a coil of magnetic area, A, traversed by the current, C. (Q.)

7.‡ Explain the construction of one or more forms of electrodynamometer, and the use of an electrodynamometer for measuring alternating currents.

8. Infer the position of equilibrium of the rectangles in Q. 3, 4, 6, or 7, and compare the direction of rotation of the current in this position with results of experiment. Q. LXXXII., XCI.

9. Show that an electric circuit tends to rotate in a magnetic field so as to include the greatest possible number of lines of force in the direction of its own force-lines, (or the smallest possible number in the opposite direction). Prob. Q.

10.‡ Describe one or more experiments illustrating the truth of the statment in the last question. D. 791.

11.‡ Describe one or more experiments showing in general the tendency of electric circuits to move so as to include a maximum number of force-lines in the direction of their own force-lines.

12. Find the work, W, done by or upon a current, C, in a wire of length, L, at right angles with the lines of force of a field of strength, F, while moving through a distance, D, in a direction at right angles with the lines of force and with the current. Q.

13.† How (if at all) must the answer to the last question be modified if L and D represent only *components* of the length of wire and motion in the directions stated?

14.‡ Explain the conventional method of plotting tubes of force so that it always takes the unit of work to cut a single tube with a unit current.

15.† Show that the phenomena in Q. 9, 10 and 11 may be explained by the principles of work.

XCII.

MAGNETO-ELECTRIC INDUCTION.

1.† State the general effect upon an electric current of (1) causing it to do mechanical work through the electromagnetic forces which it exerts, and (2) expending mechanical work upon these electromagnetic forces.

2.‡ Describe one or more experiments with an electric motor illustrating the points in the last question.

3.† What name is given to phenomena of the kind alluded to in the last two questions?

4.† Show that the phenomenon of magneto-electric induction represents one of a limited number of possibilities consistent with the general principle of the conservation of energy.

5. State LENZ'S law, and explain its bearing on the preceding questions. D. 804.

6.† Show that LENZ'S law is in keeping with the general truth that perpetual motion is impossible.

7. How must you move a north pole in the position of the thumb, when laid across the forefinger of the right hand, in order to increase a current in the direction of the forefinger? Q.

8. What motion of the conductor carrying the current in the last question would produce the same result? Q.

9.† Must a current pre-exist in a conductor in order that induced currents may be brought into play?

10. What relation between the force-lines, the motion of a conductor, and the direction of the induced current is illustrated by the forefinger and thumb? Q.

11. Can induction take place without cutting force-lines? Q.

12. State the angular relations between the active components of magnetic field, motion, and induced current. D. 805; Q.

13.† State the general relation between the magnitude of an induced current and the number of tubes of force cut in a given time. D. 807.

14.‡ Describe one or more experiments with an earth-inductor. D. 812.

15. Describe one or more experiments with a magneto-inductor. D. 803.

16. Describe one or more forms of magneto-electric machine. D. 820-823.

17. Describe one or more forms of dynamo-electric machine, and distinguish these from magneto-electric machines. D. 825.

18. Given that parallel currents attract, must they be made to approach or to recede from each other in order that they may be strengthened? Q.

19.‡ Describe one or more experiments showing that the effect of interrupting one of two parallel currents is the same as that of removing it to infinity; and that the effect of again making this current is the same as that of bringing it up from an infinite distance.

20. Find the direction of the current induced in one of two parallel wires by (1) making or (2) breaking the current through the other. Q.

21.† How long do induced currents last?

22.† Explain the transference of telephone messages between two parallel wires. (Q.)

23.‡ Explain the construction and use of a "transformer."

24.‡ Describe the construction and one or more experiments which can be performed with a "Ruhmkorff coil." D. 815, 816, 817.

25.‡ What is the use of the soft iron core in a Ruhmkorff coil?

26.‡ Explain the effect of surrounding the core of a Ruhmkorff coil with a metallic shield.

27.‡ Explain the use of metallic casings for the purpose of "damping" the swings of a magnetic needle. D. 831.

28.‡ Explain the deflection of a compass-needle by rotating a copper disc in its neighborhood.

29.† Classify different methods of current induction according to whether the magnetic field is (1) *variable* in strength, or else (if constant in strength) either (2) *movable* in position or (3) *fixed*. State also, in each case, whether the conductors in which the currents are induced are necessarily or usually movable or fixed.

XCIII.

ELECTROMOTIVE FORCE.

1. A wire of length, L, is moved through a magnetic field, F, with the velocity, V, so as to cut as many lines as possible: find the power necessary to maintain the induced current, C. Prob. Q. XXXIII.; XCI., 12.

2† What name is given to the ratio of the power spent in producing a current to the strength of the current?

3.† What is meant by "electromotive force," and to what does it correspond in hydraulics?

4. Define electromotive force, (or "EMF.") in terms of power and current. D. 740; Q. 2.

5.† Given the power, P, in watts (see Q. XXXIII.) necessary to maintain a current, C, in ampères, find the electromotive force, E, in volts brought into play.

6. Find the power in ergs per second necessary to turn a dynamo while transmitting a current of 1 absolute unit through 100,000 cm. of wire which cut through a magnetic field of 100 units strength with the average velocity of 746 cm. per second: reduce this power to watts (Q. XXXIII.), and the current to ampères (Q. LXXXIX., 14); and find the EMF. of the dynamo, in volts. Q.

7. Find the EMF. in volts of a one-horse power dynamo, while yielding a current of 10 ampères, and show that *under these circumstances* it is impossible that the dynamo should operate with any other EMF., no matter how the electrical connections are arranged. Q.

8.† Discuss the equation, EC=P; and point out an analogous equation in hydraulics. (Q. XXXIII., 10).

9. Find the maximum power in watts which can be derived from an electric motor driven by a current of 10 ampères with an EMF. of 74.6 volts, and reduce this to horse-power. Q.

10.† What usually becomes of the power spent in maintaining a current through a metallic conductor?

11.‡ Explain one or more methods of measuring the EMF. in a portion of an electric circuit by means of a calorimeter.

12. A current of 4.17 ampères generates 1 unit of heat per second (see Q. LXXI., 14) in a metallic conductor: find the EMF. between its terminals. Q.

13.‡ Describe one or more instruments capable of measuring electromotive forces, and state how these may be (roughly) tested by principles previously explained.

14. Give some idea of the EMF. of different voltaic cells, and of the effect of combining these by dissimilar poles.

15.‡ Describe one or more experiments showing that the electromotive forces necessary to maintain different currents through a given metallic conductor are proportional to the currents in question.

XCIV.

OHM'S LAW.

1.† Show that the results of the last question lead to an expression of the form, E=CR, and explain the nature of the factor, *R*.

2. What reason have we to think that the so-called "electrical resistance" of a conductor is a constant quantity, at least in the case of most metallic conductors? Q.

3. Define electrical resistance in terms of electromotive force and current. D. 739, Q.

4.† Express the electrical resistance of a conductor, *R*, measured in ohms, in terms of the electromotive force, *E*, and strength of the current, *C*, passing through the conductor.

5. State Ohm's law. D. 739.

6. How do you find the current, *C*, in ampères which an electromotive force of *E* volts will send through a resistance of *R* ohms? Q.

7.† About what length of copper wire, say 1 mm. in diameter, has been found to have a resistance of 1 ohm?

8. About what current will 1 Daniell cell send through 1 ohm? through 10 ohms? through 100 ohms? etc. Prob. Q. XCIII., 14, XCIV., 6.

9. About what current will be sent through the resistances in the last question by a battery of Daniell cells, joined in a series, the copper of one to the zinc of the next, if the battery consists of 2 elements? 10 elements? 100 elements? etc. Prob. Q.

10.† A certain Daniell cell will not send a current greater than one ampère through a wire connecting its poles, no matter how small the resistance of this wire may be: account for this fact.

11. What is meant by the "internal resistance" of a voltaic cell? Q.

12.† Find the current which a cell of electromotive force, E, and internal resistance, B, will send through a wire with the (external) resistance, R. (Q.)

13.† A cell with the constant electromotive force, E, and internal resistance, B, sends a current of C ampères through an external resistance of r ohms, and a current of c ampères through an external resistance of R ohms: find the value of E in volts and B in ohms.

14.‡ Describe and explain "OHM'S method" of determining the EMF. and internal resistance of a constant battery. D. 750; Q. 13.

15. Show that the current sent by a battery of small internal resistance through conductors of large resistance is (very nearly) inversely proportional to the external resistances in question. Prob. Q.

16. Show that the currents sent by different batteries of low internal resistance through a given conductor of high resistance are (very nearly) proportional to the electromotive forces of the batteries in question. Prob. Q.

17.‡ Explain the construction and use of a "voltmeter" for the measurement of electromotive forces.

18.‡ Describe one or more experiments illustrating OHM'S law.

XCV.

JOULE'S LAW.

1.† Show that electrical resistance can be expressed in terms of power and current, without specification of electromotive force.

2.† Find the resistance in ohms, R, of a conductor in which a current in ampères, C, is maintained by the power in watts, P, this power being transformed into heat within the conductor.

3. Find the resistance in ohms of the dynamo circuit in Q. XCIII., 6 or 7, (assuming that the dynamo is the only source of EMF.) and show that it is impossible for a dynamo of this power to yield the same current through any other resistance, no matter how the connections are made. Prob. Q.

4. Find the resistance of the metallic conductor in Q. XCIII., 12.

5.† Discuss the equation, $P=C^2 R$.

6. State JOULE'S law. D. 764; Q. 3.

7.† Show that if, by definition, $E=P/C$, OHM'S law and JOULE'S law are not independent inferences from experience; but either one is the necessary consequence of the other.

8.‡ Describe one or more experiments illustrating JOULE'S law.

9. What power in watts is necessary to maintain, in circuits of 1, 2, 3, etc. ohms resistance, currents of 1, 2, 3, etc. amperes? Prob. Q.

10. Batteries consisting of 1, 2, 3, etc. Daniell cells, (giving rise to an EMF. of 1 volt each) produce through different resistances currents of 1, 2, 3, etc. ampères: find by OHM'S law the values of the resistances in question, then by JOULE'S law, the power in watts developed in each case, and compare results with those obtained by the formula of Q. XCIII., 8. Prob. Q.

11. Find by OHM'S law the currents sent by the different batteries of the last question through resistances of 1, 2, 3, etc. ohms; then by JOULE'S law the power in watts developed in each case. Prob. Q.

12.† Find the power, P, required to maintain a current, C, not only through a resistance, R, but also against an electromotive force, E. (Q. XCIII., 8; XCV., 3.)

13.† A power of p watts is required to maintain a current of c ampères through a circuit containing only a constant resistance, R, and a constant counter-electromotive force, E; but a power of P watts is required to maintain a current of C ampères through the same circuit: find the values of R in ohms and E in volts. (Prob. Q.)

14.‡ Describe one or more experiments, with numerical examples, illustrating solutions of the last question.

15.† What interpretation must be given to negative values of E in the equations of Q. 12, 13, and 14?

16.† In the general equation,

$$P=a+b\,C+c\,C^2+d\,C^3+\text{etc.},$$

which terms are found to be of practical importance in electricity? which of no practical importance? and what names are given to the former?

17.† Compare the terms in the last question with the corresponding terms in hydraulics, and state what additional term or terms must also be considered in hydraulics.

XCVI.

CONNECTIONS IN SERIES.

1.† What necessary connection exists between the power spent in different parts of a circuit and that spent on the circuit as a whole?

2.† What is meant by connection "in series?" (D. 632).

3. Show that the strength of a current is necessarily the same in different parts of a circuit when these parts are connected together in series. Q.

4.† Show that the general expressions for EMF., power and current enable you to express the EMF. of a circuit as a whole in terms of the EMF.s of its separate parts when connected in series. (Q. XCIII., XCVI., 1, 3).

5. What in general is the EMF. in a circuit containing several sources of EMF. in series, and why? Q.

6. Several batteries with electromotive forces, E, e, etc., which are *independent of the current*, are connected in series: find the total EMF. in the circuit. Q.

7.† Explain, in terms of the power spent by or upon a current, what is meant by the opposition of electromotive forces.

8.† How must the expression in Q. 6 be modified if one or more of the EMF.s are opposed to the rest?

9.† Explain some of the advantages of (Wiedemann's method of) comparing EMF.s, when nearly equal, by opposing them.

10.‡ Describe one or more methods of comparing EMF.s by the method of opposition.

11.† When are two EMF.s known to be precisely equal?

12. If 18 Daniell cells in series exactly neutralize the EMF. of 11 Bunsen cells in series, what is the mean EMF. of a Bunsen cell in terms of a Daniell? Prob. Q.

13.† Show that the general expressions for resistance, power and current enable you to express the resistance of a circuit as a whole in terms of the resistances of its separate parts *when these parts are connected in series.* (Q. XCV., XCVI., 1, 3).

14. What in general is the resistance of a continuous metallic circuit in terms of the resistances of its separate parts? Q.

15. Show that the resistance of a wire of uniform material and cross-section is proportional to its length. Prob. Q.

16. Describe one or more forms of "rheostat" made of uninsulated wire. D. 742.

17. Describe a box of resistance coils, its use, and the object of double-winding in the coils. D. 743.

18. Several conductors give rise to the separate resistances, R, r, etc.: find the total resistance of a circuit composed of these conductors connected in series. Prob. Q.

19.† Show that the reasoning in the questions (Q. XCVI.) does not apply when the parts of a circuit are *not* connected in series.

XCVII.

FALL OF ELECTRICAL POTENTIAL.

1. In what respect are the two ends of a conductor through which a current is flowing said to differ? D. 769.

2.‡ Describe an experiment showing, by means of the electrostatic repulsion of pith-balls, differences of potential which exist between different points in a cotton thread, through which a continuous current is maintained by a Holtz-Voss machine.

3.‡ Describe an experiment with an electrometer showing differences of potential in different parts of a voltaic circuit.

4.‡ Describe an experiment with a voltmeter illustrating differences of potential which exist between different points in a metallic circuit, through the currents to which these differences of potential are capable of giving rise.

5.† What name is frequently given to the maximum difference of potential which a battery can produce between its poles?

6. Show that differences of potential may exist between two points which do not include any source of electromotive force. Q.

7.† Point out one or more cases in which electromotive forces may exist between two points which do not differ in potential.

8.† What is the general distinction between the uses of the words "electromotive force" and "difference of potential?" (Q.)

9.† To what extent can formulae for EMF. be applied to cases involving only difference of potential?

10. Find the difference of potential, E, between the two ends of a conductor of resistance, R, carrying the current, C. Q. XCIV., 1; XCVII., 8.

11. Find the difference of potential, e, between two points on the conductor in the last question, separated by the resistance, r. Q.

12. Describe the fall of potential due to a current, C, passing along a series of conductors of the resistances, R, r, etc. Q.

13. Draw (or describe) a curve illustrating the fall of potential along a conductor of uniform resistance. Q.

14. Draw (or describe) a curve illustrating the distribution of potential in a voltaic circuit. D. 749.

15.‡ Describe one or more experiments showing that the differences of potential between two points in a circuit are capable of neutralizing the EMF. of a battery. D. 753, 754.

16.‡ Describe one or more experiments showing that the electromotive forces in the last question are actually balanced, so that any variation in the conditions of the experiment will cause a current to flow either forwards or backwards through the battery.

17.† Show that the EMF. of the battery in the last two questions must be equal to the difference of potential between the two points on the conductor.

18.‡ Describe and explain Poggendorff's absolute method for determining the EMF. of a battery. (Q.)

XCVIII.

CONNECTIONS IN PARALLEL.

1. What are meant by divided circuits? by connections in parallel? or in multiple are? by a shunt? D. 747.

2.*†What necessary relation exists between the currents traversing different parts of a circuit, when connected in parallel, and the total current?

3.† Point out certain circumstances under which the ratio between two currents is known (regardless of any theory as to the particular kind of effect by which a current should be measured).

4.‡ Describe one or more experiments with divided circuits showing that the indications of an ammeter are proportional to the current. L.

5. Two dynamos, equal in every respect, and connected in parallel, give rise each to the current, C, and the electromotive force, E; find the power of each dynamo (Q. XCIII., 8), the total current (Q. 2), and the resulting EMF. (Q. XCIII., 5).

6.† Show in general that EMF. is not increased by joining two or more sources of EMF. in parallel. (Q.)

7.‡ Describe one or more experiments showing that the EMF. of two cells in parallel is not greater than that of a single cell. L.

8.† What assumption is made as to the comparative potential of two branches of a divided circuit at or near the points of junction, in the solution of problems in divided circuits?

9. Two conductors of the resistances, R' and R'', are joined in parallel, and the points of junction differ in potential by the amount, E. Find the currents C' and C'' through the two branches (Q. XCIV., 6. XCVII., 9); find also the total current, C, (Q. 2), and calculate (knowing C and E) the combined resistance, R, of the two parallel circuits (Q. XCIV., 4; XCVII., 9). Prob. Q.

10. Form a proportion (from the results in the last question) between the currents and resistances in two branches of a divided circuit. Prob. Q.

11.† State in general the relation between the resistances and currents through the several branches of a divided circuit. (Q.)

12. Express R, in Q. 9, in terms of R' and R''. Prob. Q.

13. Express $1/R$, in Q. 9, in terms of $1/R'$ and $1/R''$. Prob. Q.

14. Express in general the resistance of a divided circuit in terms of the resistances of its separate branches. D. 747.

15. What law connects the resistance of a conductor of given length and material with its cross-section? with its diameter? D. 741.

16. What is meant by the "specific electrical resistance" of a substance? D. 741.

17. Express the specific resistance, S, of a conductor of length, L, and cross-section, Q, in terms of its total resistance, R. D. 741.

18. Find the total resistance of a conductor of length, L, cross-section, Q, and specific resistance, S. D. 741.

XCIX.

BEST ARRANGEMENT OF ELEMENTS IN A CIRCUIT.

1. Find the resistance of a battery consisting of 4 cells of 4 ohms resistance each, when arranged (1) in series, (2) in parallel, and (3) in 2 parallel series containing 2 cells each. Q.

2. Find the EMF. of the battery in Q. 1, (1), (2) and (3), assuming that the EMF. of each cell is 1 volt. Q. XCVI., 6; XCVIII., 6.

3. Find the cnrrent in ampères due to each of the battery arrangements in Q 1 and 2 when connected with an external resistance of 4 ohms. Q. XCIV., 12.

4. Find the effect of substituting for 4 ohms, in the last question, a resistance of 16 ohms, or any other resistance (say 1600 ohms) not less than the maximum internal resistance. Q.

5. Find the effect of substituting for 4 ohms, in Q. 2, a resistance of 1 ohm, or any other resistance (say zero ohms) not greater than the minimum battery resistance. Q.

6. Under what circumstances would you prefer to connect the battery in Q. 1 in series? in parallel? in some other way? Q.

7. Find the resistance of a circuit containing 4 telegraph instruments of 4 ohms resistance, each, when connected (1) in series, (2) in parallel, and (3) in 2 parallel series containing 2 instruments each: and find the current through the circuit, in each case, due to each of the three battery arrangements in Q. 1 and 2. Q.

8. Under what circumstances would you prefer to arrange the telegraph instruments in the last question (1) in series, (2) in parallel, and (3) in some other way? Prob. Q.

9. A cable consisting of 4 strands of 4 ohms resistance, each, is wound about a core of soft iron so as to form an electromagnet: how should these strands be connected for use with a battery having an internal resistance of 1 ohm? 4 ohms? 16 ohms? Q.

10.† How should the resistance of an electromagnet of given weight or given dimensions compare with that of the battery? (Q.)

11.† Show that the conclusion in the last question does not (in general) apply if the size of wire is specified, but not the dimensions of the electromagnet.

12. Find the power in watts developed by each of the battery arrangements in Q. 1 and 2 in an external circuit consisting of 4 incandescent lamps of 4 ohms resistance, each, connected (1) in series, (2) in parallel, and (3) in 2 parallel series containing 2 lamps each. Q. XCVII., 5; XCIX., 3, 4, 5, 7.

13.† What relation must exist between the external and internal resistances in a circuit, in order that a maximum of power may be developed in the former? (Q. 12).

14 † Find the heating effiiciency of the combinations in Q. 12.

15. Show that the maxima of heating power and heating efficiency do not coincide. Q. 14.

16.‡ Describe one or more experiments illustrating the best arrangement of elements in an electric circuit under different conditions.

17.† State a practical rule of wide (but not universal) application to the adjustment of resistances in a circuit.

18.† Criticise any *unqualified* statement to the effect that external and internal resistances should be made equal.

19.† Point out certain absurdities to which a statement like that of the last question, unless properly qualified, would be apt to lead.

WHEATSTONE'S BRIDGE.

1. What name is given to a cross-connection between two parallel circuits? D. 756.

2.† Show that if two parallel wires, each of uniform material and cross-section, (but not both necessarily of the same material or cross-section) be connected in parallel, any two opposite points must have the same potential, and that in consequence no current will flow across a Wheatstone's bridge joining these points.

3. What proportion exists between the four parts into which two parallel circuits are divided by a Wheatstone's bridge, adjusted as in the last question? D. 756.

4.‡ Describe the British Association form of Wheatstone's bridge apparatus, and state when it is known to be in adjustment.

5.† Show that uniform currents, C and c, flow one through each of the two parallel circuits of a Wheatstone's bridge when in adjustment.

6. Show that the fall of potential, E, between the first junction and the bridge is the same for both circuits when in adjustment; also that the fall of potential, e, between the bridge and the second junction is the same for both circuits. Prob. Q.

7. Find the resistance of each of the four sections into which the bridge divides the two parallel circuits in the last two questions, and find a proportion between these resistances. Q.

8.† What proportion, in general, holds between the four "arms" of a Wheatstone's bridge? (Q.)

9.‡ Explain the measurement of unknown resistances by means of a Wheatstone's bridge apparatus. D. 756.

10.‡ Show that a Wheatstone's bridge apparatus may be used to measure unknown resistances many times greater or less than any of the known resistances which it contains.

11.† Show by a diagram that the battery and galvanometer of a Wheatstone's bridge may be made to change places without disturbing the adjustment of the apparatus.

12.‡ Describe one or more experiments illustrating the "reversibility" of a Wheatstone's bridge.

CI.

HEAT DEVELOPED IN A CONDUCTOR.

(See Q. LXXXI., 3; XCIII., 10, 11; XCV., 2).

1.† Describe one or more experiments showing that conductors become heated by continuous currents which pass through them. D. 763.

2.‡ Explain how the resistance of a conductor can be measured by calorimetric principles. L.

3.† Find the resistance in ohms of a wire in which a current of C ampères generates heat enough to raise m grams of water T degrees, Centigrade, in t seconds, allowing 4.17 watt-seconds to 1 unit of heat. Q.

4. Substitute in the last question, for C, 1, 2, or 3, etc., ampères; for m, 100, 200, or 300, etc., grams; for T, 1, 2, or 3, etc., degrees; for t, 417, 834, or 1251, etc., seconds. Q.

5. What law connects the rise of temperature in a calorimeter with the current? with the resistance? with the time? with the thermal capacity of the water, etc.? Q.

6. Find the number of heat units developed in a conductor of resistance in ohms, R, by a current in ampères, C, in t seconds, allowing 4.17 watt-seconds to the unit of heat. Q.

7. Find the number of heat units developed in the conductor of the last question if the difference of potential between its terminals is E volts.

8.† What limits the maximum temperature attained by a conductor while transmitting a current?

9. Explain why some parts of a continuous circuit may become overheated, while other parts remain relatively cool. D. 766.

10.† Explain the use of a safety-fuse.

11.‡ Describe certain processes of electrical smelting.

12.‡ Describe an ordinary incandescent lamp. D. 865, A.

13. Describe an arc lamp—the voltaic arc. D. 862-864.

14.† Is the heating effect of a current reversed when the current is reversed?

15. Explain the heating effects of alternating currents. Q.

16. How is it possible to maintain an incandescent lamp at a white heat with a current which has no effect upon a galvanometer? Q.

17.† Name certain substances whose resistance decreases with the temperature.

18.† State the usual effect of a rise of temperature on the resistance of a conductor.

19.† Give some idea of the increase of resistance of metals with a rise of temperature.

20.† Explain the maintenance of any accidental maximum of temperature by an electric current. (Q.)

CII.

THE THOMSON AND PELTIER EFFECTS.

1.† Describe one or more experiments illustrating the dislocation of maxima of heat in a conductor by an electric current. D. 771.

2. What happens when a current flows from the hot part of a conductor to the cold part? or the reverse? D. 771.

3. What is meant by the "Thomson effect?" D. 771; (Q.)

4. Is the Thomson effect the same in direction for all metals? D. 776.

5. What happens when a current of electricity is passed across a junction between two dissimilar metals? D. 771.

6. How is the effect in the last question altered by a change (1) in the magnitude and (2) in the direction of the current? D. 771.

7. What is meant by the "Peltier effect?" D. 771.

(See farther, Q. CVIII.)

CIII.

THERMO-ELECTRICITY.

1. What happens when a junction between two dissimilar metals is heated or cooled? D. 768.

2.† What is meant by a thermo-electric current? by a thermo-electric junction? by a thermo-electric pair?

3.‡ Describe one or more experiments in thermo-electricity. D. 768, 769.

4.† What are meant by thermo-electric heights? (D. 776, A.)

5.† Show, by considering the necessary succession of elements in a circuit, that thermo-currents must depend upon *differences* in temperature. (D. 777).

6.† Name two metals giving rise to thermo-currents which are nearly proportional to the difference in temperature between the two junctions.

7.† Does the proportionality between thermo-currents and differences in temperature usually hold through wide limits? (D. 772-774).

8.† Name two metals showing a reversal of the thermo-current between them when a certain temperature is reached.

9.† What conditions must be fulfilled in order that temperatures may be measured accurately with a thermo-junction? (Q.)

10.‡ Describe the construction and use of a thermo-pile. (D. 777).

11.‡ Describe the construction and method of using a thermo-battery. (D. 777).

12.† Give some idea of the amount of power which can practically be derived from thermo-electric sources.

CIV.

ELECTROLYSIS.

1.‡ Describe one or more experiments illustrating the transmission of currents by liquids. D. 725.

2.‡ Describe one or more methods of finding the specific resistance of a liquid.

3.‡ Describe an experiment showing that power is required to maintain a current through a liquid even when the resistance is reduced to zero.

4.† What becomes of the power spent as in the last question?

5. What is meant by electrolysis? by an electrolyte? by an electrode? D. 725.

6. Define cathode, cathion, electropositive, anode, anion, electronegative. D. 725.

7.† Are metals cathions or anions? electropositive or electronegative? carried with or against the current?

8.† Compare oxygen, chlorine, and other non-metallic elements with metals in respect to the points mentioned in the last question.

9.† Where does hydrogen stand in the electropositive or electronegative series?

10.† What happens when a current is passed between two electrodes placed in the sea, thousands of miles apart?

11. Explain (Grotthus' hypothesis concerning) the "transport of elements." D. 726.

12.‡ Describe the electrolysis of water in a "gas voltameter." D. 725.

13. Compare the volumes of oxygen and hydrogen set free in a gas voltameter. D. 725.

14.† How can you tell a positive from a negative (battery) pole by means of a gas voltameter?

15.† Which electrode of a voltameter is called positive? and which negative?

16.† Show that the positive pole of a battery corresponds to a negative electrode, and *vice versa*. (Q.)

17.‡ What usually happens when a current of electricity is passed between two metallic electrodes, through a solution of some salt formed by the metals in question? D. 729.

18.† How can you tell a positive from a negative (battery) pole by means of a metallic salt solution?

CV.

ELECTROPLATING.

1.‡ Describe one or more processes of electroplating. D. 735.

2.‡ Describe one or more experiments showing that electroplating can be removed by a reversal of the current by which it was produced.

3.† State certain conditions of success in plating with copper, and with metals in general.

4. Describe one or more processes by which electrotypes are produced. D. 737.

5. Describe processes of silver, gold, and nickel plating used in the arts. D. 736.

6.† To what metals are electroplating industries at present chiefly confined?

7.† Name certain alloys which can be deposited by electrolysis.

8.† Name some twelve or more metals which can be deposited by electrolysis in a comparatively pure state.

9.† What metals are purified electrolytically on a commercial scale?

10.† Describe the electrolytic refinement of copper.

CVI.

ELECTROCHEMICAL EQUIVALENTS.

1.† How many grams of copper does one ampère deposit in some 50.8 minutes?

2.‡ Explain the construction and the measurement of currents by means of a copper voltameter. (D. 729).

3.‡ Describe a silver voltameter, and state its chief advantage over a copper voltameter. (D. 729).

4.† Give some idea of the volume of (1) oxygen and (2) hydrogen liberated in a gas voltameter by a current of 1 ampère in one minute.

5. What relation exists between the weights of copper, silver, oxygen, or hydrogen liberated by a given current in a given time? D. 730.

6. What is meant by the "electrochemical equivalent" of a given element? D. 730.

7. State the relation between electrochemical equivalents, atomic weights, and valency. D. 730.

8. State the law of electrochemical equivalents. D. 730.

9. Name one or more causes which are likely to interfere with the exact fulfilment of the law of electrochemical equivalents. D. 730.

10. Compare the quantities of copper deposited in a given time by a given current from solutions of cupric and cuprous salts. D. 730.

11.† Is it the quantity of the metallic or of the non-metallic element which is usually constant in cases like that of the last question, and why?

12.† What invariable relation exists between the quantity of electricity which passes through an electrolyte and the number of (supposed) atomic bonds which are formed or broken?

CVII.

ELECTROCHEMICAL RELATIONS WITH ELECTROMOTIVE FORCE.

1.‡ Describe one or more experiments showing that the development of a given amount of heat by a voltaic cell is accompanied by the solution of a corresponding amount of metal.

2.‡ Describe one or more experiments showing that when a given amount of heat is developed by a battery in an outside circuit, an equivalent amount fails to appear within the battery itself.

3.† Point out the source of energy in a voltaic battery. D. 731.

4.† Explain how, through the chemical actions by which it is always accompanied, power be absorbed or developed by a current.

5.‡ Describe the construction and advantages of various forms of voltaic cell, especially the Daniell, the gravity, the Bunsen, the bichromate (dip), and the Leclanché cell. D. 695-708, A.

6.† Explain the chemical actions which take place in the cells mentioned in the last question.

7.† If Q is the electrochemical equivalent of a metal in grams per second per ampère, H its heat of combination in units of heat per gram, and J the mechanical equivalent of the unit of heat in watt-seconds, find the power, P, in watts spent upon a current, C, in ampères flowing from the metal to the liquid with which combination takes place. (D. 731).

8. Find by previous principles the electromotive force, E, developed by the action in the last question, and show that this EMF. is independent of the current. Q. XCIII., 4.

9. If one ampère dissolves 0.000337 grams of zinc per second, if one gram of zinc gives out 1500 units of heat in combining with the fluid of a certain battery, and if one unit of heat is equivalent to 4.17 watt-seconds, find the electromotive force of the battery in question, assuming that the only action to be considered is the solution of the zinc. Prob. Q.

10. If one ampère deposits 0.000328 grams of copper per second, and if one gram of copper requires 700 units of heat to separate it from the battery fluid of the last question, find the counter-electromotive force in this battery due to the deposition of copper. Prob. Q.

11.† Why is the electromotive force of a Daniell or of a gravity cell less than that of most zinc-carbon elements? (Q.)

12.† Upon what assumption (concerning the development or absorption of heat caused by currents passing through a battery) are the calculations of electromotive force in preceding questions justified?

13.† Describe and explain one or more experiments illustrating departures of observed from calculated electromotive forces.

14.† What is meant by "polarization" of the plates of a battery or voltameter? (D. 704).

15. Explain what is meant by a secondary battery. D. 732.

16. Describe Faure's lead plate accumulator. D. 733.

17. State Planté's improvement upon Faure's accumulator. D. 733.

18.‡ Describe one or more forms of modern storage batteries, and give some idea of what can be accomplished with them.

CVIII.

RECIPROCAL RELATIONS BETWEEN ELECTRICAL SOURCES AND EFFECTS.

(See Q. LXXXI., 7; XCII., 1-6).

1. What, according to LENZ'S law, is the relation between the direction of a current causing a given motion in a given electro-magnetic system, and that of the current induced by the same motion of the same system? Q. XCII., 5, 6.

2.‡ An electric motor is connected through a galvanometer with a battery, and when at full speed, the battery is suddenly *shunted* out of the circuit: describe and explain the effect of this change upon (1) the speed of the motor and (2) the deflection of the galvanometer. Q.

3.‡ Describe one or more experiments with a thermo-battery substituted for the motor in the last question.

4.‡ Describe one or more experiments with a storage cell substituted for the motor in Q. 2.

5.‡ Show that electrostatic condensers yield results similar to those in the last three questions.

6. State in each of the four cases mentioned above, the relation between the direction of the current causing a given primary effect, and that of the current arising as a secondary effect, having this primary effect as a cause. Q. 2-5.

7.‡ Power is applied to a dynamo so as to send a current through a galvanometer and battery in series, the EMF.s acting in the same direction: state and explain the effect of the battery current upon the dynamo when the power is cut off. (Q.)

8.‡ Describe one or more experiments with a thermo-battery similar to that in the last question.

9.‡ Describe one or more experiments with a storage cell similar to that in Q. 7.

10.† What would be the obvious effect upon an electrostatic condenser of a forced continuation of the current for a short time after its complete discharge?

11. State, in each of the last four questions, the relation between the conditions which produce a current in a given direction and those which result from a forced continuation of this current in the same direction, after the previous conditions have ceased to exist. Q.

12.† Discuss the validity of inferences as to the generality of the facts stated in Q. 6 and 11.

13.† Given that a current, *in either direction* through a conductor (of uniform material) will produce heat, what general principle would enable you to anticipate the fact that heating a conductor (of uniform material) will *not* produce a current *in either direction*?

14.† Show that reciprocal relations between cause and effect do not generally exist unless the reversel of one is accompanied by the reversal of the other. (Q. 13).

15.† On what grounds might one expect to derive a current from a change in position of a maximum of heat in a conductor of uniform material? (Q. CII., 3; CVIII., 12).

16.‡ Describe one or more experiments illustrating the point in the last question.

17.† Does the Thomson effect involve a storage or accumulation of energy, or only a transference of energy (without increase either in quantity or intensity) from one part of a conductor to another?

18. Indicate a significant point of difference between the Thomson, and other reversible effects of an electric current, which might lead you to anticipate the results of Q. 16.

19. State two possible reasons why a current cannot be derived from the reversed action of the Thomson effect. Q. 13, 18.

20. What two conditions appear to be necessary to the existence of reciprocal relations between cause and effect? Q. 14, 18.

21.‡ Describe one or more experiments illustrating the relation between the directions of the currents in a coil of great self-induction before and after the source of EMF. has been cut off, and the bearing of these experiments upon Q. 6, 11, and 12.

22.† Point out the necessity, exemplified by preceding questions, of extreme caution in making scientific generalizations.

END OF PART III.

QUESTIONS ON GENERAL PHYSICS.

PART IV. (*A*).—SOUND.

CIX.

TRANSMISSIBILITY OF SOUND.

1.*‡Describe the effects of exhausting the air from a receiver in which a sounding body is placed. D. 868.

2.* How do we know that air carries sound? D. 868.

3.‡ Describe and explain one or more experiments illustrating the function of sounding-boards in transmitting vibrations to the air.

4.*‡ Describe one or more experiments illustrating the transmission of sound through solids. D. 868.

5.‡ Describe one or more experiments showing that sound is transmitted by bodies of water. D. 868.

6. Through what kinds of substance is sound propagated? (Are these substances ponderable or inponderable?) D. 868.

7.* How is the velocity of sound in air determined? D. 868.

8.* Give some idea of the velocity of sound in air, under ordinary conditions. D. 868.

9. State the effects of temperature, pressure and humidity upon the velocity of sound in air. D. 876.

10. Give some idea of the velocity of sound in liquids and solids. D. 879, 880.

CX.

SOUND AND VIBRATION.

1.* Describe one or more experiments showing that sound is accompanied by vibration. D. 866.

2.‡ Describe the use of a "vibroscope," or other instrument by which the vibrations of a solid may be registered upon a moving surface. D. 896. L.

3. Describe the "phonautograph," or other means of tracing vibrations of the air on a moving surface. D. 896.

4. Describe one or more forms of "phonograph." D. 928.

5.† State obvious points of similarity between the phonograph, phonautograph, vibroscope, and other forms of chronograph.

6.† Distinguish the phonograph from other forms of chronograph in respect to the relative direction of the impressed vibrations with respect to the moving surface.

7. Explain the reproduction of sounds by means of a phonograph. D. 928.

8.† Show that the reproduction of sounds by means of a phonograph is evidence of their accurate registration.

9.*†Describe one or more experiments showing that, in general, vibrations (within certain limits of frequency) are accompanied by sound. D. 895.

10.‡ Describe one or more experiments showing a gradual transition from vibrations which can be counted to sonorous vibrations. D. 866; L.

11. Give some idea of the maximum and of the minimum number of vibrations, executed in one second, which is capable of affecting the ear. (D. 893).

12. How do we know that sound consists in vibration? Q.

CXI.

LOUDNESS, PITCH, AND CHARACTER.

1. Name certain instruments which enable us to record and study vibrations corresponding to different sensations of sound. Q. CX., 2, 3, and 4.

2.* What is meant by "amplitude" of vibration, and what quality in the sensation of sound is dependent upon it? D. 889.

3.* Upon what physical basis does the loudness of a sound depend? D. 889.

4.* What is meant by "regularity" of vibration, and what kinds of sounds are characterized thereby? D. 867.

5.* State the physical distinction between a "noise" and a "musical sound." D. 867.

6.* What is meant by "rate" or "frequency" of vibration, and with what sensation does it correspond? D. 889.

7.† When is a musical sound said to have a definite "pitch?"

8.* Upon what physical basis does the "pitch" of a musical sound depend? D. 889.

9.† What is meant by a musical "note," in the physical (and general) sense of the word?

10. What is meant by the "form" of a vibration, and what influence may this have upon the sensation produced by a musical note of given loudness and pitch? D. 889.

11. Upon what physical basis does the "character" of a musical note depend? D. 889, 925; Q. CXVIII., 4-7.

12. Name the (three) qualities of a musical note (aside from its duration). D. 889.

13.† What is the principal idea conveyed by the word "tone" as applied to a musical instrument?

14.† Distinguish a "simple tone" (or a "tone" according to some authors) from a musical note in general.

15.† When are two instruments said technically (by musicians) to be sounding the "same note?" (*e.g.* the note C)?

16.† Distinguish the more technical or restricted use of the word "note," in music (as in Q. 15), from its general use in physics and in ordinary language. Q. 9-11.

CXII.

RESONANCE.

1.† Distinguish sympathetic from forced vibrations.

2.† Describe an experiment with two pendulums of the same length, illustrating the phenomenon of "sympathetic vibrations." D. 904.

3.† Describe one or more experiments with tuning-forks, illustrating selective sympathetic vibrations.

4.† When will a body capable of vibration respond to the vibration of another body? (D. 904).

5.† Describe one or more experiments with Leconte's sensitive flames.

6.† What is meant by a resonator? (D. 926).

7.† Describe the use and construction of a simple form of resonator (consisting of a jar partly filled with water).

8.† Explain the advantage of the use of resonators to persons devoid of musical ear.

9.‡ Describe one or more experiments with Helmholtz's resonators. (D. 926).

10. Explain the analysis of vowel sounds by Helmholtz's resonators. D. 927.

11.‡ Describe one or more experiments illustrating the response of the cavity of the mouth to different notes when shaped so as to sound different vowels. D. 927.

12.† To what extent should the vibrations of sounding-boards, diaphrams, mouth-pieces of wind instruments, manometric flames, singing flames, etc. be classed under the head of sympathetic (as distinguished from forced) vibrations?

CXIII.

MAINTENANCE OF VIBRATIONS.

1.‡ Describe and explain an experiment showing that a vibrating tuning-fork comes to rest more rapidly when connected with a resonator than when held in mid-air.

2.* Show that some source of energy is necessary for the maintenance of a vibration, and illustrate by examples.

3.† Show that the maintenance of vibrations depends upon the periodic application of force.

4.† What relation must exist between the frequency of impulses and that of the vibrations maintained thereby?

5.‡ Describe and explain the experiment with the "Trevelyan rocker." D. 866.

6.† Describe and explain one or more experiments illustrating the maintenance of vibrations by means of electrical contacts.

7.‡ Describe and explain one or more experiments with "singing flames." D. 866, 909.

8.‡ Describe and explain the maintenance of vibrations by means of a resined bow. D. 866, 909.

9. Explain the action of a "flute mouth-piece." D. 910.

10. How is the vibration of "reed-pipes" maintained? D. 918.

11.† Point out in each case which you have studied (1) the source of energy by which the vibration is maintained; (2) the mechanism by which this source of energy is caused to develop forces in the right direction at the right time; (3) the extent to which the natural period in the supply of energy controls the rate of vibration in the sounding body; and (4) to what extent the natural rate of vibration of the sounding body determines that of the supply of energy. Q. 5-10.

CXIV.

LAWS OF VIBRATION.

1.† Distinguish transverse, longitudinal and torsional vibrations. (D. 899).

2. State the laws connecting the rate of vibration of a string (1) with its length, (2) with its tension and (3) with its mass. D. 901.

3.‡ Describe one or more experiments illustrating the laws of the vibration of strings. D. 902.

4.† Describe one or more experiments illustrating the effects of length, breadth, and thickness on the rate of vibration of a rod fixed at one end, or supported at two points; and state the results of these experiments.

5. What law of wide application connects the size and vibration frequency of two bodies of the same shape and material? D. 909, 912.

6. State the "law of linear dimensions." D. 909, 912.

7.* To what kind of bodies are transverse (and torsional) vibrations confined?

8.† State the law connecting the torsional vibration of a rod with its length, etc.

9. State the law connecting the rate of longitudinal vibration with the length of the vibrating body (1) in the case of strings, (2) in the case of rods, and (3) in the case of thin columns of air. D. 905, 913.

10.‡ Describe one or more experiments illustrating the laws of vibration of pipes as connected with their length.

11.† What allowance must be made for the diameter of the open end of a pipe in order that the law just stated may be accurately fulfilled?

12. Give some idea of the generality of the application of the law of linear dimensions. D. 909, 912; Q.

CXV.

MUSICAL INTERVALS.

1. Within what limits of pitch are the notes employed in music usually confined? D. 893.

2. Give some idea of the vibration frequency of the "middle C" of a piano (*i. e.*, the "C" between the base and treble staffs). D. 892.

3. State the number of vibrations corresponding to the consecutive notes, C, D, E, F, G, A, B, and C, (in the natural scale of C) beginning with ($11\times24=$) 264 vibrations per second. Prob. D. 891, 892.

4. Find the smallest whole numbers to which the vibration frequencies in the last question are accurately proportional. D. 891.

5. What is meant by the "gamut" or "diatonic scale," and by what names are its elements usually designated? D. 891.

6. In what respect are the significations of the names, Do, Re, Mi, Fa, Sol, La, Si, Do, more general than those of the notes, C, D, E, F, G, A, B, C? D. 891.

7. What is meant by the "musical interval" between two notes? D. 890, 891.

8. Define the following musical intervals:—a unison, a semitone, a minor tone; a major tone (or second), a third, a fourth, a fifth, a sixth, a seventh, an octave. D. 890, 891.

9. Distinguish two uses of the word "tone" (1) to denote a musical interval and (2) to designate a musical sound. Q. CXI., 13, 14; CXV., 8.

10 What names are applied to the following musical intervals:—1/1, 16/15, 10/9, 9/8, 5/4, 4/3, 3/2, and 2/1? D. 890, 892.

11. What is meant, in general, by an "interval of n octaves and an mth?"

CXVI.

HARMONY AND DISCORD.

1.† When are several notes said to belong to a "harmonic series?"

2. What name is given to the lowest note of a harmonic series? D. 903.

3. What name is (generally) given to notes of a series whose vibration frequencies are integral multiples of a given vibration frequency? D. 903.

4.† State the distinction between a musical note and a chord (or a discord).

5.† Distinguish between chords and discords.

6.† State the musical intervals between the three principal notes of one or more chords frequently employed in music.

7. Name certain musical intervals which give rise to discords. D. 929.

8.† Distinguish a discord from an ordinary noise, or unmusical sound.

9. Show that harmony between different notes depends in general upon the simplicity of the ratios expressing the musical intervals between them. D. 929.

CXVII.

LISSAJOUS' CURVES.

1.‡ Describe one or more instruments capable of drawing, automatically, the resultant of two vibrations at right-angles.

2.† Under what circumstances will a spot of light, vibrating rapidly in two directions at right-angles, execute what appears to be a continuous curve to the eye?

3. What are meant by Lissajous' curves? D. 932.

4.† Plot Lissajous' curves corresponding to the musical intervals, 1/1, 2/1, 3/1, etc., assuming that both vibrations reach their extreme limits at the same moment. (D. 922).

5.† Plot curves corresponding to the same musical intervals as in the last question, assuming that the slower vibration reaches its extreme at the moment when the faster vibration is at its middle point. (D. 922).

6.† What relation exists between the number of lobes in a Lissajous' curve, obtained as in the last question, and the ratio of the vibration frequencies in question? Q.

7.† Explain the change of form in a Lissajous' curve representing an approximate, but not an exact musical interval.

8.† Plot Lissajous' curves corresponding to the musical intervals, 3/2, 4/3, 5/4, etc.

9.† What musical interval gives rise to a Lissajous' curve similar to the letter I? the letter O? the letter S? the letter U? the figure 8? the figure 3? etc. (D. 922).

10.‡ Describe one or more methods of producing Lissajous' curves. (D. 922).

11. Describe one or more processes of optical tuning, depending upon the use of Lissajous' curves. D. 923.

CXVIII.

COMPOSITION OF PARALLEL HARMONIC VIBRATIONS.

1.† Explain the graphical method of compounding vibrations parallel to a given line.

2.† Find the result of superposing, graphically, simple tones whose vibration frequencies are proportional to the integers, 1, 2, 3, etc.

3.† Under what circumstances may the pitch of a note, compounded as in the last question, agree with that of its fundamental tone?

4. In what respect may the quality of a musical note be altered by combining, with its fundamental tone, simple harmonics in small but varying proportions? Q. CXI., 10, 11; Q. CXVIII.

5.‡ Describe one or more experiments illustrating variations in the character of musical notes produced by different combinations of simple harmonics with their fundamentals.

6. Contrast the sensation produced by a simple tone with that of a note containing an abundance of harmonics. D. 926.

7.‡ Describe one or more experiments illustrating the production of different vowel sounds. D. 927.

CXIX.

BEATS.

1. When are two vibrations said to have the same "phase?" when different "phases?" when opposite "phases?"

2.† Find the effect of superposing (graphically) two simple vibrations of the same frequency, but in different (not opposite) phases.

3.† State the effect of superposing two simple vibrations of the same frequency (1) in the same phase and (2) in opposite phases.

4.† How are the results obtained as in the last question modified if the amplitude of the two vibrations happens to be the same?

5.† Explain the fact that the sound emitted by two tuning-forks of the same pitch, though generally louder, is sometimes feebler than that due to either of the forks alone.

6.† Find (graphically) the result of superposing two simple vibrations of the same amplitude, but of slightly different pitch. (D. 888).

7.* What are meant by "beats" in acoustics? D. 888, 932.

8.* Explain the production of beats. D. 888, Q. 6.

9.‡ Describe one or more experiments illustrating the production of beats.

10.† How do you tell which is the higher of two notes giving rise to beats?

11. Find a relation between the pitch (P and p) of two notes, and the number of beats (n) to which they give rise in one second. D. 888.

12.‡ Explain the use of a "tonometer," or other instrument for the determination of pitch by timing beats. D. 897, Q.

CXX.

NODES AND ANTINODES.

1.‡ Describe one or more experiments illustrating the transmission of waves by a medium.

2. What is meant by the wave-length of a vibration of given frequency in a given medium? D. 869.

3.† Find a relation between the velocity of sound, its frequency of vibration, and its wave-length. (D. 869, 889, 937).

4.† Show that points in a medium, 1, 2, 3, etc., wave-lengths apart, are in the same phase of vibration.

5.† Show that points in a medium 1/2, 3/2, 5/2, etc. of a wave-length apart, are in opposite phases of vibration.

6.† What happens when sound from any source is transmitted by a given medium to a given point by channels differing by an even number of half wave-lengths? by an odd number of half wave-lengths? (Q. CXIX., 3; CXX., 4, 5).

7.‡ Describe and explain one or more experiments illustrating the reinforcement and the interference of sound in double channels of unequal length.

8.‡ Explain the determination of the wave-length of sound by methods of interference.

9. What name is given to a point or region in a medium where interference constantly takes place? D. 887.

10. What are meant by nodes and antinodes? D. 887.

11.† Two waves of the same frequency and amplitude and in the same phase start, one from A toward B, the other from B toward A; find the condition of a point, P, half-way between them; also of points 1, 2, 3, etc., quarter wave-lengths on either side of P.

12. Explain the formation of nodes and antinodes in a medium transmitting waves of given amplitude and frequency in opposite directions. D. 887; Q.

13.† Show that any medium which can transmit waves in opposite directions must be capable of vibrating in nodes and antinodes.

14.† Distinguish transverse, longitudinal, and torsional vibrations. (D. 899).

15.‡ Describe one or more experiments showing that strings are capable of vibrating transversely in nodes and antinodes. (D. 903).

16. Describe one or more experiments illustrating the longitudinal vibration of columns of air in nodes and antinodes.

17.† What is the effect of damping a vibration at a node? at an antinode?

18.† What is the result of cutting a hole in a vibrating pipe at a node? at an antinode?

19. Why must the stopped ends of pipes coincide with nodes, and the open ends with antinodes? Q. 17, 18.

20. How are the nodes distributed in open pipes? D. 913, I.; Q.

21. Explain the distribution of nodes in pipes stopped at one end. D. 913, II.; Q.

22.‡ Describe one or more experiments illustrating the existence and distribution of nodes in the transverse vibration of rods, whether clamped at one end, or supported at two points.

23.‡ What are meant by Chladni's figures, and how are they produced? D. 907.

CXXI.

OVERTONES.

1. What in general is the effect of an increase in the number of nodes upon the pitch of the note emitted by a vibrating body? D. 907.

2. What name is given to the lowest note which a vibrating body is capable of emitting? D. 903.

3. What name is given to notes emitted by a vibrating body higher than its fundamental tone? D. 913.

4.† In what class of instruments is the fundamental tone (or that part of it which is persistent) simple (in the sense of being free from overtones)? (D. 908).

5. In what classes of (musical) instruments is the fundamental tone accompanied by an abundance of overtones? D. 903, 905, 913.

6. Give instances of vibrating bodies whose overtones are not harmonics of their fundamental tone. D. 907.

7. In what classes of (musical) instruments are the overtones harmonics of the fundamental tone? D. 903, 913.

8. Name certain musical intruments whose overtones form (1) a complete and (2) an incomplete series of harmonics. D. 903, 913.

9. State the musical interval (if harmonic) between the fundamental tone and the successive overtones (1) in strings (2) in open pipes, (3) in pipes closed at one end and (4) in rods, plates, bells, etc. D. 903, 907, 908, 913.

10.† Distinguish simple from complex overtones.

11.† In what restricted sense are the words "overtone" and "fundamental tone" used by some authors?

12.† What extended meaning is sometimes attached to the words "fundamental note" and "harmonics?"

CXXII.

RADIATION OF SOUND.

1.‡ Describe one or more experiments showing how a disturbance at a point spreads over the surface of a liquid.

2.‡ How is the phenomenon in the last question modified when the original disturbance is a curved line?

3. Describe the shape of the waves emanating from a disturbance at a point in a (homogeneous and isotropic) medium of three dimensions. D. 871, 1080.

4. Find the law governing the diminution of the loudness of a sound at different distances from its origin. D. 871.

5. State the law of inverse squares as applied to the energy of wave-motion in general. D. 465, 871, 946.

6. What is meant by the dissipation of sonorous energy? D. 872.

7. Describe and explain the phenomenon of change of pitch consequent upon relative motion of the source of sound with respect to the recipient agent. D. 898.

8. If the velocity of sound is 330 m. per sec., how fast must a train move to sharpen the note of its whistle by 1 semitone? and why? D. 898.

9.† Show that relative motion may change the apparent direction of sound.

CXXIII.

RECTLINEAR PROPAGATION.

1.‡ Describe one or more experiments illustrating the independence of different systems of waves on a surface.

2. Give some idea of what is meant by the "principle of Huygens." D. 1079.

3.† Give some idea of what is meant by the "principle of least time" and its connection with the principle of Huygens.

4.† Apply the principle of Huygens to the course followed by a portion of a spherical wave when the rest is cut off (D. 1080).

5.† Explain the (approximately) rectilinear propagation of a portion of a wave passing through an orifice. (D. 1080).

6.‡ Describe one or more experiments due (1) to Colladon and (2) to Leconte, illustrative of sound shadows. (D. 937).

7.† What is meant by a "ray" of sound (or other form of energy propagated in waves)? by a "pencil" of rays? by a beam? (D. 882).

8. State the angular relation between the "ray" and the wave-front in a (homogeneous isotropic) medium. D. 882.

9.† Describe the course of those portions of a wave near the edge of an obstacle when the neighboring portions are cut off.

10. Describe one or more (familiar) experiments illustrating the bending of sound-waves around an obstacle.

11. What in general is meant by "diffraction." D. 1080.

12.† What general relation exists between the length of a wave, the width of an orifice, and the proportion of rays suffering diffraction?

CXXIV.

REFLECTION.

1.‡ Describe one or more experiments illustrating the reflection of waves.

2. What is meant by an "echo?" D. 884.

3.† Under what circumstances is the reflection of sound accompanied by a reversal of phase?

4.‡ Describe one or more experiments illustrating change of phase by reflection at an antinode.

5.† Explain the vibration of pipes closed at one end as the result of a series of reflections with or without change of phase.

6. Explain the formation of a wave-front by reflection. D. 882.

7. What is meant by the angle of incidence of a ray or of a wave? by the angle of reflection? D. 952.

8. Find by geometrical construction the relation between corresponding angles of incidence and of reflection. D. 1082.

9.‡ Describe one or more experiments illustrating the laws of reflection of sound.

10.† Prove that the broken path, ABC, of a ray AB reflected from B to C, by a plane mirror at B, making equal angles with AB and BC, is the shortest possible path from A to C by way of the mirror.

11.‡ Describe and explain one or more experiments showing that sound waves may be concentrated by a concave mirror. D. 883.

12. What is meant by a focus? D. 966.

CXXV.

REFRACTION.

1. In what way, other than by reflection, may a sound wave be brought to a focus? D. 883, note.

2.‡ Describe an experiment showing that sound waves may be concentrated by a lens. D. 883, note.

3.† Explain the action of a spherical bag filled with carbonic dioxide gas in rendering sound waves in air convergent.

4.† What is meant by refraction, and under what circumstances will it take place? (D. 1090).

5.† Draw a diagram illustrating the refraction of a ray in crossing obliquely the surface separating two media, and indicate in which medium the velocity is greatest. (D. 981).

6. What is meant by an "angle of refraction?" D. 983.

7. Explain (by graphical construction) the formation of a wave-front in a refracting medium. D. 1081.

8. Find by geometry the relation between the velocity of sound in two media, in terms of the sines of the angles of incidence and refraction. D. 1081.

9.† Prove that the broken path, ABC, of a ray, AB, refracted in the direction BC (as in Q. 8), at a plane surface passing through B, is the quickest possible path from A to C through the plane surface.

10. Explain the principle of "least time," as applied to the rectilinear propagation, to the reflection, and to the refraction of sound. D. 1084.

END OF PART IV. (*A*).

QUESTIONS ON GENERAL PHYSICS.

PART IV. (*B*).—LIGHT.

CXXVI.

NATURE OF RADIANT HEAT AND LIGHT.

1.‡ Describe one or more experiments illustrating phenomena attributed to the radiation of heat.

2.‡ Describe one or more experiments showing that radiation, like the conduction (but unlike the convection) of heat, does not depend upon motion of the medium which transmits it. D. 457; L.

3.‡ Describe one or more experiments showing that radiation, unlike conduction and convection, may take place without warming the medium through which heat is transferred. D. 457, 479; L.

4.‡ Describe one or more experiments showing that radiation, unlike conduction and convection, is practically instantaneous. D. 457; L.

5.‡ Describe one or more experiments showing that a ponderable medium is not necessary for the propagation of radiant heat or light. D. 458, 936.

6. State four fundamental points of difference between radiation, and conduction or convection. Q. 2-5.

7.* What is meant by a "transparent" medium? by a "diathermanous" medium? by a medium which is "opaque" to heat or light? (D. 479, 480).

8.‡ Describe one or more experiments illustrating the transmission of electromagnetic impulses through different media.

9.† State four fundamental points of analogy between electromagnetic vibration and radiant heat or light. (Q. 6 and 8).

10.† With what class of phenomena are radiant heat and light thought to be closely associated? (Q. 9).

11.*† State and explain the effects of radiant heat and light upon the temperature of (opaque) bodies by which they are intercepted. (D. 469, (3)).

12.† Explain why (according to the electromagnetic theory) good conductors of electricity are as a class opaque to light and heat, while transparent or diathermanous bodies are as a rule good insulators of electricity.

13.† Describe one or more experiments showing that a supply of energy is necessary to maintain a source of radiant heat or light.

14.† Under what circumstances and at about what rate is heat radiated from one body to another? (D. 470).

15. What is meant by the theory of exchanges? D. 464.

16.‡ Describe and explain one or more experiments illustrating the (apparent) "radiation of cold."

17.‡ Describe one or more experiments, similar to those of the last question, which might be held (with equal propriety) to illustrate an (apparent) "radiation of darkness."

18.* What relation is believed to exist between the natures of radiant heat and light? D. 457.

19.‡ Describe one or more experiments showing that radiant heat and light are incapable of producing warmth or vision, without farther transformation.

20. Is radiant heated considered, strictly speaking, as a form of heat? Give reasons. D. 457; Q.

21.† What is meant by the statement that light (as such) is invisible? (Q.)

22. What name is given to the medium by which radiant heat and light (and possibly electromagnetic vibrations in general) are carried from one place to another? D. 936.

23.* What is meant by the (luminiferous) "ether?" and to what in acoustics does it correspond? D. 936.

24.† Contrast the "Undulatory" and the "Corpuscular" theories of light, and state which of them is supposed to be in accordance with fact. (D. 936, 1083).

CXXVII.

VELOCITY OF LIGHT.

1. Explain how Roemer deduced the velocity of light from the eclipses of Jupiter's satellites. D. 944.

2. Explain Fizeau's method of measuring the velocity of light by means of a toothed wheel. D. 941.

3. Describe Foucault's apparatus for measuring the velocity of light by a revolving mirror. D. 942.

4. Give some idea of the velocity of light in air (or in vacuo). D. 944.

5. How does the velocity of light in water (or other refracting media) compare with its velocity in vacuo? D. 942.

6.† Point out the bearing of the facts alluded to in the last question upon the truth of the Undulatory and Corpuscular theories of light. (Prob. D. 1083, and Q. 5).

7. Compare the velocity of light with that of sound. Q.

8.† State the results of experimental determinations of the velocity with which electromagnetic impulses are transmitted through air.

9.† Point out the significance of the agreement of electromagnetic vibrations with radiant heat and light in respect to velocity, as evidence of identity in the nature of these phenomena.

CXXVIII.

COLOR AND ALLIED PHENOMENA.

1.† What three classes of vibration (of which one only is luminous) are included under the study of light?

2.† About what is the relative amount of energy (as measured by heating effects) due to the luminous as compared with the non-luminous vibrations in sunlight? in lamplight? in the electric arc light? (D. 482).

3.* What are meant by invisible heat rays? or calorific rays? (D. 482).

4.*†Which of the three classes of vibration in Q. 1 is most important to the photographer?

5.*†What are meant by photographic rays? by actinic rays? by chemical rays?

6.† How do the rays of light most active in effecting chemical changes compare in heating power with (1) luminous rays? and (2) invisible heat rays? (D. 482).

7.† Give some idea of the limits of vibration frequency within which optical effects are produced. (D. 1099).

8.† State the effect of a variation in the amplitude of a luminous vibration.

9. Upon what does the luminosity, brightness, or intensity of any illumination depend? Q. 8.

10.† What is the effect of narrowing the limits of vibration frequency in light?

11. Upon what does the purity of a color depend? Q. 10.

12.† What is meant by perfectly pure (or monochromatic) light?

13.† State the effect of any change in the (average) frequency of luminous vibrations.

14. Upon what does the "hue" or color proper of light depend? Q. 13.

15.† Give some idea of the rates of vibration characterizing different hues. (D. 937).

16. What are the "three constants of color?" D. 1074.

17.‡ Describe one or more experiments showing the impossibility of producing the sensations due to pure red, green, or violet light by the mixture of lights not already suggestive of the colors in question.

18.† Name and explain what are meant by the three "primary color sensations." D. 1075.

19.‡ Describe one or more experiments showing that the sensations due to pure blue and yellow lights, as well as different sensations of "purple," may be produced by the mixture of red, green, and violet lights in different proportions.

20.† Why are blue, yellow, and purple considered to be complex color sensations? (Q. 19).

21.† Explain why the complex sensations of blue and yellow can be produced by pure (monochromatic) light, while the complex sensation of purple cannot thus be produced.

22.‡ Describe one or more experiments illustrating the composition of ordinary white light.

23.† What are meant by (1) ultra-red and (2) ultra-violet rays?

24.† What is meant by a red heat? a yellow heat? a white heat? by incandescence in general?

25.† Give some idea of the correspondence between the temperature of an incandescent solid and the prevailing hue of the light which it emits.

26. What is meant by calorescence? D. 482.

27.‡ Describe one or more experiments illustrative of fluorescence. D. 481, 1051.

CXXIX.

STATIONARY LUMINOUS VIBRATIONS.

1.‡ Describe one or more experiments showing that luminous vibrations of a given frequency, when communicated to certain bodies, continue to exist for some time after the source has been cut off. D. 1051.

2. What name is given to the phenomenon in the last question? D. 1051.

3.† State evidence pointing to the existence of free luminous vibrations in bodies. (Q.)

4. What is meant by "phosphorescence?" D. 1051.

5. Why are all phosphorescent bodies (either) fluorescent (or calorescent)? D. 1051.

6.† Give some idea of the (supposed) molecular action accompanying absorption or emission.

7. What general relation exists between absorption and emission (or radiation)? D. 470.

8. Why are good reflectors and good transmitters of heat necessarily poor absorbers? Prob. D. 469.

9.† What two classes of surfaces are the poorest absorbers, and (accordingly) the poorest radiators of heat? what is the prevailing color of these surfaces? and why?

10.† What substances are the best abscobers, and (accordingly) the best radiators of heat? what is the prevailing color of these substances? and why?

11.† Name certain marked exceptions to the rules for color in the last two questions.

12. To what cause are the colors of ordinary surfaces and transparent media attributed? D. 483, 1067, 1068.

13. How do we explain differences in color between two self-luminous bodies at the same temperature? D. 483.

14. What is meant by selective absorption and emission? D. 483.

15.‡ Describe one or more experiments illustrating the interchangeability of selective absorption and emission due to elevation or reduction of temperature. (D. 483).

16.‡ Describe one or more experiments illustrating conditions under which selective absorption and emission (at a given temperature) are always interchangeable.

17.† In what class of substances are powers of selective absorption and emission most marked?

18.‡ Describe one or more experiments illustrating the production of characteristic flame-colors. (D. 1055, 3; 1056).

19.‡ Describe one or more experiments with flame-colors suggestive of sympathetic vibrations. (D. 1057).

20.‡ Describe one or more experiments illustrating the selective action of thin films. D. 1100.

21.† State the application of the "law of linear dimensions" to the colors of thin fissures, as seen by transmitted light.

22.‡ Describe "Newton's rings" as seen by transmitted light.

22.† Explain how the wave-lengths of differently colored lights are measured by means of Newton's rings.

24. Express the velocity, V, of light in any medium in terms of its wave-length, L, in that medium, and the number, N, of vibrations executed in one second. D. 937; Q. CXX., 3.

25. Show how the rates of vibration corresponding to different colors may be determined by Newton's rings. Q. 23, 24.

26.‡ Describe one or more phenomena (connected with the composite colors of moderately thin films) showing that the same space may respond to two or more rates of vibration at the same time.

27.† Describe a process of color photography depending upon the production of nodes and antinodes near a reflecting surface.

28.‡ Describe one or more experiments illustrating the interference of luminous vibrations in opposite phases, and point out the significance of the phenomena in question with respect to the wave-theory.

CXXX.

PRINCIPLES UNDERLYING PHOTOMETRY.

1. What according to the principle of Huygens is the shape of a wave-front of light (in a homogeneous isotropic medium)? D. 1080.

2. Explain the rectilinear propagation of light by the principle of Huygens. D. 1080.

3.‡ Describe one or more experiments illustrating the rectilinear propagation of radiant heat and light. D. 459, 937.

4.† Describe one or more experiments illustrating the applicability of the law of inverse sqnares to (1) light, (2) heat, and (3) photographic rays. (D. 465, 946, L.)

5. State and explain the principle made use of in various forms of photometer. D. 947-950.

6. Explain the use and construction of a Rumford's photometer. D. 948.

7. Describe a rudimentary form of Bunsen's photometer which can be easily constructed. (D. 950).

CXXXI.

ABERRATION AND CHANGE OF COLOR DUE TO THE EARTH'S MOTION.

1. What is meant by the "aberration" of light? D. 945.

2.† How is the aberration of light accounted for by the wave-theory?

3.† Express the (tangent of the) angle of aberration of light, A, in terms of the velocity of light, V, and the transverse velocity, v, of the earth in its orbit.

4. Give some idea of the magnitude of the aberration of light. D. 945.

5. Explain (minute) changes in the colors of stars, due to the earth's relative motion, according to the wave-theory. D. 1059.

6. Give some idea of the amount of changes of color due to the earth's motion. D. 1059.

CXXXII.

DIFFRACTION OF LIGHT.

1.‡ Describe one or more experiments illustrating diffraction in light. (D. 1092, et seq.)

2.† Explain the unequal diffrangibility of light and sound as the result of a difference in the ratio of the wave-length to the diameter of the orifice or obstacle in question. (D. 937).

3. Describe the construction of a diffraction grating. D. 1098.

4. Find the relation between the wave-length of light, and the angle through which it is bent from the perpendicular by a grating with a given distance between its lines. D. 1094.

5. What data are necessary for the determination of the wave-length of any kind of (monochromatic) light by means of a diffraction grating? D. 1094, 1095.

CXXXIII.

REFLECTION OF LIGHT.

1. Distinguish regular from irregular reflection. D. 955.

2.‡ Describe one or more experiments illustrating the laws of reflection for (1) light, (2) heat, and (3) photographic rays. (D. 466-468, 952).

3.‡ Describe one or more experiments illustrating the difference in the appearance of thin films (*e. g.* Newton's rings) as seen by reflected and by transmitted light.

4.† Quote experimental evidence in favor of the inference that waves of light in a given phase are reflected perpendicularly by the inner and outer surfaces of a medium in opposite phases of vibration. (Q.)

5.† Give some idea of the proportion of light reflected perpendicularly by different surfaces.

6.† State in general the dependence of the proportion of light reflected upon the angle of incidence.

7. What is meant by total internal reflection? D. 987.

8.‡ Describe one or more experiments illustrating total internal reflection. (D. 987).

9. What is meant by the "critical angle" of total internal reflection? D. 987.

CXXXIV.

REFRACTION OF LIGHT.

1.‡ Describe one or more experiments illustrating the similarity of the laws of refraction for (1) light, (2) heat and (3) photographic rays.

2. Distinguish and explain the phenomena known as "looming" and "mirage." D. 1089.

3.† What is meant by the "index of refraction" of a medium? (D. 986).

4. What relation exists between the velocities of light, V and v, in two media, and the index of refraction, I, in question? D. 1081.

5. Find a relation between the wave-lengths of light, L and l, in two media, and the index of refraction, I. Prob. Q. CXXIX., 24; CXXXIV., 3.

6. State the "law of sines" governing the refraction of a ray of light entering a medium. D. 983.

7.‡ Describe one or more experiments illustrating the law of sines. D. 984, 985.

8. Find the relation between the angle, A, of a prism, its index of refraction, I, and the deviation, D, of a ray passing through it, so as to make equal angles with the two sides adjacent to A. D. 995.

9. Explain a construction showing the deviation of a ray passing through a prism. D. 996.

10. Show that a ray passing symmetrically through a prism (as in Q. 8) is bent less than any other ray. D. 996.

11. What is meant by the position of minimum deviation for a prism? D. 995.

12. What data are necessary for the determination of the index of refraction of a prism for rays of a given wave-length? (Q.)

13. Upon what constant does the "critical angle" depend? D. 987.

14. Find the relation between the index of refraction, I, and the critical angle, A, of a medium. D. 987.

15.‡ Describe one or more instruments for determining indices of refraction by observing critical angles of total internal reflection.

CXXXV.

ANALOGIES BETWEEN SOUND AND LIGHT.

1.† Show that sound and light are analogous in that (1) both consist (supposably) in vibration, and (2) require energy for their maintenance, which is (3) transformed into heat by an absorbing medium, but (4) may pass through a non-absorbing medium without being permanently imparted to it; in that (5) motion of the medium as a whole is not necessary to the transference of this energy; in that (6) this transference is always from a place of more intense to one of less intense vibration, and (7) at a rate depending upon the difference of intensity in question; in that (8) both sound and light obey the law of inverse squares in respect to the rate of transference of energy; in that (9) both are incapable of affecting the senses except when transformed into stationary vibrations of some sort, and then only (10) by vibrations lying within certain limits of frequency, giving rise, within these limits to (11) three sense-constants, depending upon (12) amplitude, (13) frequency, and (14) form of vibration; in that (15) both are subject to the transformation of slower into faster and (16) faster into slower vibrations; in that (17) both present cases of bodies with free vibrations, and (18) bodies with (more or less marked) natural periods of vibration; leading to phenomena of (19) selective absorption and emission and (20) sympathetic vibration; in that (21) both travel with definite velocity and (22) have definite wave-lengths in a given medium, (23) which are equal to the quotient of their velocity by their frequency, and hence (24) follow, under similar conditions, the law of linear dimensions, (25) exhibit cases of vibration in nodes, and (26) harmonics; in that (27) both follow geometric laws for

the composition of vibrations, and hence (28) present similar interference phenomena; in that (29) both follow the principle of Huygens, and accordingly (30) the principle of least time; in that (31) both give rise to spherical wave-fronts, (32) are propagated in straight lines through a homogeneous medium, (33) obey the same laws for external reflection, as concerns direction and (34) amount; (35) suffer total internal reflection under similar circumstances, and (36) a change of phase by internal reflection; in that (37) both travel with diminished velocity in a refracting medium, (38) obey the same law of sines in refraction, and (39) bend round an obstacle (of the same relative size as compared with the wave-length) according to the same law; and in that (40) both suffer an apparent change of direction or (41) frequency owing to relative transverse or longitudinal motion of the source and the observer. (Q.)

2. Name some forty points of analogy between sound and light. Q. 1.

3.† Give names, when they exist, to analogous phenomena in light and sound. (Q. 1).

4. What in light corresponds (1) to the three classes of vibration in sound (of which one only is audible)? (2) to the three qualities of a musical note? (3) to loudness? (4) to pitch? (5) to character? (6) to a simple tone? (7) to resonance? (8) to sympathetic vibrations? (9) to the laws of pipes closed at both ends? (10) to nodes? (11) to harmonics? (12) to reflection at a node? (13) to reflection at an antinode? (14) to bending around corners? (15) to change of pitch due to relative motion? etc. Q. 1.

5. What in sound corresponds (1) to heat rays? (2) to light rays? (3) to photographic rays? (4) to the three constants of color? (5) to luminosity? (6) to hue? (7) to purity? (8) to monochromatic light? (9) to calorescence? (10) to fluorescence? (11) to phosphorescence? (12) to selective emission? (13) to the interchangeability of selective emission and absorption? (14) to the pure colors of thin films? (15) to the composite colors of moderately thin films? (16) to indices of refraction? (17) to reflection

at the outer surface of a refracting medium? (18) to reflection at the inner surface of a refracting medium? (19) to diffraction? (20) to minute changes of color in stars due to the earth's motion? etc. Q. 1.

6.† Name two or more points of analogy between sound and light which are thought to be explanable by the wave-theory, only. Q. CXXVII., 5, 6; CXXX., 1; CXXXI., 5.

7.† Name some twenty or thirty points of analogy between sound and light which have been thought to be explanable by the corpuscular theory, and show that a theory should not be accepted by strength of analogy alone.

8. State evidence, founded upon previous questions, in favor of the wave-theory as distinguished from the corpuscular theory of light. Q. 6, 7.

9.† State one or more significant points of difference between sound and light. Q. CXXVI., 5; CXXVII., 7.

CXXXVI.

DISPERSION.

1. What is meant by the "dispersion" of light? D. 1047.

2.‡ Describe one or more experiments illustrating dispersion. D. 1045-1047.

3. How are the colors of the rainbow accounted for? D. 1066.

4.† Explain the dispersion of light according to the wave-theory.

5.† Why does not sound, like light, give rise to phenomena of dispersion?

6.‡ Describe one or more methods of analyzing colors by means of dispersion.

7. What is meant by a "spectrum?" D. 1047.

8.‡ Describe the spectrum due to absorption by differently colored glasses.

9. Explain variations in brightness in different parts of the spectrum. D. 1049.

10.† What is meant by an absorption band? and what is the angular relation of such bands to the plane of refraction?

11. What name is given to an absorption band when it becomes very narrow? D. 1049.

12. What are meant by the Fraunhofer lines of the solar spectrum? D. 1049, 1055 (1).

13. Describe the spectra of most incandescent solids and liquids. D. 1055 (2).

14. Describe the spectra of ordinary artificial lights. D. 1060.

15. Describe certain spectra which are characterized by bright lines. D. 1055 (3).

16. How do the spectra due to light emitted by vapors compare with absorption spectra due to the same vapor? D. 1057.

17.‡ Describe and explain one or more experiments illustrating the reversal of brightness in lines of the spectrum. D. 1057.

18.‡ Describe one or more methods of recognizing certain chemical elements by means of their spectra. (D. 1056); L.

19. How do we know that certain chemical elements are present in the sun? D. 1057.

20.† How may minute differences in color be observed by means of a spectrum? (Q.)

21. Give grounds for the inference that the earth is approaching some stars and receding from others. D. 1059.

22.† How are colors usually distributed in a spectrum due to ordinary (not anomalous) dispersion, with respect to wave-length and frequency?

23.† What is meant by anomalous dispersion?

24.‡ Describe one or more experiments (with crossed prisms) illustrating anomalous dispersion.

25.† What relation is found frequently to exist between selective absorption and retardation?

26.† Give some idea of the distribution of colors in a 60-degree flint glass prism.

27.† Give some idea of the indices of refraction of (1) flint glass and (2) crown glass for *different rays*.

28.† What is meant by an index of dispersion?

29.† What connection frequently exists between indices of refraction and dispersion?

30.‡ Explain the possibility of constructing a prism so as to bend rays of different colors equally (*i. e.* to produce refraction without dispersion).

31.‡ Explain the possibility of constructing a prism so as to bend some rays, and to leave others unbent (*i.e.* to produce dispersion without general refraction).

32.† What is meant by a "direct vision" combination (*e. g.* of prisms)?

33.† What is meant by an "achromatic" combination (*e. g.* an achromatic prism or an achromatic lens)? (D. 1063, et seq.)

CXXXVII.

PLANE POLARIZATION.

1.‡ Describe one or more experiments (*e. g.* with Malus's polariscope) showing that the properties of a beam of light are not always isotropic with respect to the beam as an axis. D. 1101, 1102.

2. When and why is light said to be polarized? D, 1101.

3. How can polarized light be distinguished from ordinary unpolarized light? Q.

4.† Why cannot the phenomena connected with the polarization of light be explained (like phenomena in sound) by the wave-theory of *longitudinal* vibration?

5.† In what respect are the vibrations of polarized light thought to differ from those of sound? (Q. 4).

6.‡ Describe one or more experiments with Malus's polariscope illustrating exceptions to the general rule that the quantity of light reflected by a surface increases with the obliquity. (D. 1102).

7. What is meant by the "polarizing angle" of any substance? D. 1102.

8. Define "plane of polarization." D. 1103.

9.† What is the angular relation between the plane in which a beam of light is said to be polarized, and the direction of the electric vibration in which the beam is supposed to consist?

10.† In what respect are the vibrations of polarized light supposed to differ from those of ordinary (unpolarized) light, and on what grounds?

11. What crystal is noted for its power of absorbing light polarized in one plane, and transmitting light polarized in a plane at right-angles with the first? D. 1105.

12.‡ Describe and explain one or more phenomena connected with the polarization of light by tourmaline plates. D. 1101, Q.

13. State some (of Melloni's) results showing that radiant heat can be polarized. D. 1117.

14.† How would you show that photographic rays can be polarized?

15. Name several sources of plane polarized light. D. 1101-1104.

16. What is meant by the "polarizer" and what by the "analyzer" of any combination? D. 1101.

17. Name the essential parts of a "polariscope."

CXXXVIII.

ROTATION OF THE PLANE OF POLARIZATION.

1.† Under what circumstances may the amount of light transmitted through a polariscope be increased by placing a transparent medium between the polarizer and analyzer?

2.‡ Describe one or more experiments showing that the plane of polarization of a beam of light may be rotated by certain substances. D. 1112.

3. When is the rotation of the plane of polarization said to be right-handed, and when left-handed? D. 1112.

4. What is the distinction between right-handed and left-handed quartz?

5.‡ Describe one or more experiments showing that the amount of rotation in the plane of polarization depends upon the color of the light in question.

6. Explain the production of colors by (unequal) rotation of different planes of polarization. D. 1112; Q. 5.

7. Point out the advantages of the use of monochromatic light in an exact measurement of the angle through which a given plane of polarization has been rotated. Q.

8. State the law usually connecting the amount of rotation with (1) the strength and (2) the depth of a solution.

9.‡ Explain the construction and use of one or more forms of saccharimeter.

10. Describe one or more experiments illustrating magneto-optic rotation. D. 1113.

11. State a fundamental point of difference between magneto-optic and ordinary rotation of the plane of polorization. D. 1113.

12. Why cannot ordinary rotations of the plane of polarization be explained as special cases of magneto-optic action? Q. 11.

CXXXIX.

CIRCULAR AND ELLIPTIC POLARIZATION.

1.† A ray of plane polarized light passes along the line of intersection of two planes at right-angles to each other, but oblique to the direction of vibration: what will be the effect of any cause producing a relative retardation of the component of this vibration in one plane, amounting to (1) a wave-length? (2) a half wave-length? (3) a quarter wave-length? (4) intermediate fractions of a wave-length?

2. What is meant by circular polarization? and by elliptic polarization in general? D. 1114.

3.† Show that rays of light circularly (or elliptically) polarized must behave in certain respects like unpolarized rays (or partially polarized rays, respectively).

4.‡ Describe and explain one or more experiments (with Fresnel's rhombs) illustrating the production of circular or elliptical polarization by oblique internal reflection. (D. 1114).

5.‡ Describe one or more experiments indicating that glass, when subjected to certain strains, has the property of unequally retarding the two components of vibration in plane polarized light.

6.‡ Describe one or more experiments showing that plates of selenite are capable of producing elliptic or circular polarization. (D. 1114).

7. What is meant by a "quarter-wave" plate? by a half-wave plate? D. 1114.

8.‡ Compare certain phenomena due to a half-wave plate with those due to rotation of the plane of polarization through a right-angle.

9. Explain the production of colors by plates of selenite in a polariscope. D. 1108.

10.‡ Describe one or more experiments illustrating the production of colors by elliptically polarizing media. D. 1107.

11.† State the relation between the plane of polarization of the incident light and the "axis of strain," in Q. 5, or the "axis" of the crystral, in Q. 6, 8 or 10, when adjusted for the maximum effect in each case.

12.† In what way are phenomena due to elliptic polarization affected by making the axis of the crystal producing them parallel to, or perpendicular to the plane of polarization of the incident light and why?

13.‡ Point out some of the uses of a polariscope for studying the constitution of crystals.

14. State certain points of analogy and difference between rotary and elliptic polarization. Q.

15.‡ What happens when a ray of circularly polarized light is passed through a combination, itself capable of producing circular polarization? D. 1114, paragraph 3.

16.† Explain the possibility of transforming elliptically polarized light into plane polarized light by means of an elliptically polarizing medium. (Q. 15).

17.† Describe and explain one or more points of distinction between ordinary unpolarized (or partially polarized) light, and light which is circularly polarized (or elliptically polarized, respectively). (Q.)

CLX.

DOUBLE REFRACTION.

1.† What is meant by a "uniaxal" crystal?

2.† Draw two or more sections of the wave-front due to polarized light (1) in a homogeneous isotropic medium, (2) in a crystal with axis perpendicular to the plane containing all the vibrations, and (3) in the same crystal with axis parallel to this plane.

3. What is meant by the "ordinary" and what by the "extraordinary" ray in a uniaxal crystal? D. 1105.

4. Show that the ordinary ray in a uniaxal crystal obeys the law of sines. D. 1105.

5. Show that the extraordinary ray in a uniaxal crystal does not obey the law of sines. D. 1105.

6.† Give some idea of the mechanism by which a ray of unpolarized light, entering a crystal, is decomposed into an ordinary and an extraordinary ray.

7. What is meant by "double refraction?" Q.

8.† Explain the phenomenon of double refraction in uniaxal crystals.

9.† Show that circular or elliptic polarization is a special case under double refraction.

10.† Show that all doubly refracting media must exhibit, under certain circumstances, phenomena of elliptic polorization.

11.† What is considered the most delicate test for double refraction?

12.‡ Describe one or more experiments illustrating double refraction. D. 998.

13.‡ Describe one or more experiments showing that the separate images due to double refraction consist of light polarized in two planes at right-angles.

14. Describe the construction and use of a "Nicol" (or a "Foucault") prism. D. 1106.

15.† What are meant by "biaxal" crystals?

16.† State some of the most important distinctions between the laws for refraction in uniaxal and biaxal crystals.

17.† Describe some of the peculiarities of the wave-front or wave-fronts due to unpolarized light in a biaxal crystal.

18.† What is meant by "conical refraction," and how was it discovered?

19.† Explain, by numerous examples, the application of the principle of least time to optics. (D. 1084).

20.† Point out at least one exception (in double refraction) to the general application of the principle of least time, and explain this by a more general principle (relating to maxima or minima). (D. 1084).

CLXI.

SHADOWS.

1. What is meant by a shadow? D. 939.

2. Distinguish between the umbra and the penumbra of a shadow. D. 939.

3. Explain a geometrical construction by which the limits of the umbra and penumbra may generally be determined.

4. Make one or more drawings showing the shapes of the umbra and penumbra in special cases. D. 939.

5.‡ Describe one or more experiments illustrating effects of umbra and penumbra.

6.† When does the shadow cast by an orifice approximate to the shape of the orifice, and when to the shape of the luminous body casting the shadow?

7.‡ Describe one or more experiments illustrating the point in the last question.

8. Explain the formation of images by a small orifice. D. 938.

9.† Describe the "pin-hole camera," and explain its action.

10. Show that images formed by small apertures are inverted. (D. 938).

11.† State the law connecting the relative size of an object and its image produced by a small orifice, and the relative distances of the object and image from the orifice.

12.† Why is distance between the screen and the orifice, as well as smallness of the orifice desirable when the best definition, regardless of brightness, is desired?

CLXII.

REAL IMAGES FORMED BY CONCAVE MIRRORS.

1. What is meant by spherical aberration? D. 974.

2. What is meant by the "caustic" of a mirror? D. 974.

3.‡ Describe one or more experiments illustrating the shape of caustics. D. 974.

4. What are meant by the two "focal lines" of a mirror, and how are they usually related to each other? D. 975.

5.‡ Describe one or more experiments illustrating the production of focal lines by a concave mirror.

6.† Under what circumstances does a spherical mirror bring light approximately to a focus?

7. What is meant by the "principal focus," and what by the "principal focal length" of a concave mirror? D. 968.

8. What are meant by "conjugate foci," and by "conjugate focal lengths" of a concave mirror? D. 967.

9. Explain the production of real images by a concave mirror. D. 970.

10. Show that a real image formed by a concave mirror is always inverted. D. 970.

11. Find a relation between the relative sizes of an object and its (real) image, formed by a concave mirror, in terms of their relative distances from the centre of curvature of the mirror. D. 971.

12. Find, by geometry, a relation between the relative distances of object and image from the centre of curvature of a mirror and their (mean) relative distances from the mirror itself. D. 967.

13. Show that the diameters of object and image are proportional to their respective (mean) distances from the mirror. D. 971; Q.

14. Express the radius of curvature of a concave mirror in terms of any two conjugate focal lengths. Prob. Q.

15. Find an expression for the reciprocal of the radius of curvature of a concave mirror in terms of the reciprocals of any two conjugate focal lengths. D. 967; Prob. Q.

16. Find a relation between the radius of curvature of a concave mirror and its principal focal length. D. 968.

17. Find a relation between the reciprocal of the principal focal length of a concave mirror and the reciprocals of any two conjugate focal lengths. D. 968.

18. Find (1) the principal focal length and (2) the radius of curvature of a concave mirror with conjugate focal lengths, 5 and 20 cm. Prob. Q.

19.† Show that the laws for conjugate focal lengths are consistent with the assumption that a concave mirror always imposes a certain degree of convergence upon the rays which strike its edges.

20.‡ Describe one or more experiments illustrating the formation of real images by concave mirrors, and the law governing the sizes and positions of such images.

21. Express the relative size of object and image in terms of (1) the relative distance of mirror and object from the principal focus, and (2) the relative distance of mirror and image from the principal focus. Prob. D. 971; Q.

22. Where would you place a concave mirror of 40 cm. focal length, and where would you place the screen, in order to form an image of an object enlarged 4 times upon the screen? Prob. Q. 21.

CLXIII.

IMAGES IN PLANE MIRRORS.

1.*†Why cannot a mirror, unless it be concave, form real images of objects?

2.† What is meant by the "image" of an object in a plane mirror? D. 977.

3. Distinguish a virtual image from a real image. D. 977.

4. Where is the image of a point in a plane mirror? D. 957.

5. Prove that a point and its image in a plane mirror must be symmetrically situated with respect to the reflecting surface. D. 957.

6. Describe the image of an object in a plane mirror. D. 957.

7.† Is the position of an image in a plane mirror definite for one position of the observer, only, or is it the same for all positions from which the image can be seen?

8.‡ Explain the location of an image in a plane mirror by the "method of parallax."

9.‡ Describe one or more experiments illustrating the fact that the image of an object in a plane mirror is as far behind the mirror as the object is in front of it.

10. State the law connecting the angular rotation of a mirror with the angular deviation thereby produced in the images of fixed objects reflected by the mirror. D. 964.

11.‡ Describe and explain one or more instruments for measuring angles by the rotation of a mirror (*e. g.* the optical lever; the telescope, mirror and scale; or the sextant). (D. 965).

12. What general principle enables you to solve problems in multiple reflection? D. 958.

13. Explain the multiple images produced by parallel mirrors. D. 959.

14. Explain one or more cases in which multiple images are produced by mirrors inclined at different angles. D. 960,961.

CXLIV.

IMAGES IN CONVEX MIRRORS.

1. What kind of image (real or virtual) is formed by a convex mirror? Q. CLXIII., 1.

2.† Explain a construction for the location of the virtual image of any object in a convex mirror, and state whether such an image is erect or inverted. (Q. CLXII.)

3. Find the relation between the diameter of an object and its image in a convex mirror in terms of their relative distances (1) from the centre of curvature of the mirror, and (2) from the mirror itself. Q. CLXII., 11, 12, 13.

4.† Show that the virtual image of an object in a convex mirror is smaller than the object.

5.† Why do images in convex mirrors seem (in certain respects) farther off than the objects which produce them?

6. Show that the virtual image of an object in a convex mirror is in point of fact nearer to the mirror than the object is. Q. 3, 4.

7.† What are meant by the conjugate focal lengths of a convex mirror?

8.† Find an expression for the radius of curvature of a convex mirror in terms of any two conjugate focal lengths, and show that, by treating certain terms as essentially negative, the expression becomes identical with that applicable to concave mirrors. (Q. CLXII., 14).

9.† Show that the expression in the last question is consistent with the fact that a given convex mirror always imposes a given divergence upon the rays which strike its outer edges.

10.† Is the radius of curvature of a convex mirror considered essentially positive or negative, and why? (Q. 8).

11.† When are conjugate focal lengths considered positive, when negative, and why? (Q. 8).

12.† What is meant by the principal focal length of a convex mirror? Is this real or virtual? positive or negative? and why? (Q. 8).

CXLV.

VIRTUAL IMAGES IN CONCAVE MIRRORS.

1. Under what circumstances does a concave mirror give rise to a virtual image? and why? D. 976.

2. Describe a construction showing the position of the virtual image of any object in a concave mirror, and state whether it is erect or inverted. D. 976.

3.† Find a relation between the sizes of an object and its virtual image in a concave mirror in terms of their relative distances (1) from the centre of curvature of the mirror and (2) from the mirror itself. (Q. CLXII., 11, 12, 12).

4.† Show that the virtual image of an object in a concave mirror is larger than the object.

5.† Why do virtual images in concave mirrors seem in certain respects nearer to us than the objects producing them?

6. Show that the virtual image of an object in a concave mirror is in point of fact farther from the mirror than the object is. Q. 3, 4.

7. Show that, by considering virtual focal lengths as essentially negative quantities, the expressions for the radius of curvature and principal focal length of a concave mirror in terms of the conjugative focal lengths become applicable to cases where one of the images is virtual. (Q.)

CXLVI.

REFRACTION AT A CURVED SURFACE.

1.† The (small) convex surface of a medium of index of refraction, I, and radius of curvature, R, focusses rays which are parallel (1) within the medium or (2) outside of the medium at a distance, F, from the surface. Find, in each case, the relation between I, R, and F. (D. 1015).

2.† The convex surface of a medium of index of refraction, I, and radius of curvature, R, collimates (*i.e.* makes parallel) rays emanating from a point (1) within the medium or (2) outside of the medium at a distance, F, from its surface. Find, in each case, the relation between I, R, and F. (D. 1015).

3.† The concave surface of a medium of index of refraction, I, and radius of curvature, R, makes rays which are parallel (1) within the medium or (2) outside of the medium diverge as if from a point at a distance, F, from the surface. Find, in each case, the relation between I, R, and F. (D. 1015).

4.† The concave surface of a medium of index of refraction, I, and radius of curvature, R, makes rays which would otherwise converge to a point at the distance, F, from the surface, parallel (1) within the medium or (2) outside of the medium. Find, in each case, the relation between I, R, and F. (D. 1015).

5.† Let I be the relative velocity of parallel rays in a given medium, before refraction, as compared with their velocity after refraction, and R the radius of curvature of the convex or concave refracting surface, giving rise to a real or virtual focus at the distance, F. Find a general expression connecting I, R, and F. (Prob. Q.)

6.† Show that the general expression in the last question can be applied to the case also of convex or concave mirrors, by considering I equal to -1. (Prob. Q.)

CXLVII.

IMAGES FORMED BY LENSES.

1. What is meant by a plano-convex, a plano-concave, a convexo-concave, a concavo-convex, a double convex, a double concave, a converging, or a diverging lens? D. 1000.

2. What is meant by the optical centre of a lens? by its principal axis? by its (real or virtual) principal focus? or conjugate foci? D. 1001, 1002.

3.† Find the principal focal length of a plano-convex lens in terms of its index of refraction and radius of curvature.

4.† Find the virtual principal focal length of a plano-concave lens in terms of its radius of curvature and index of refraction.

5. Rays passing through a double convex lens are parallel within it; the index of refraction of the lens is I, and the two radii of curvature, R and r. Find the two conjugate focal lengths. Prob. Q. CXLVI., 1 (1), 2 (2).

6. Extend the demonstration in the last question to the cases of (1) a convexo-concave lens, (2) a concavo-convex lens, and (3) a double concave lens. Prob. Q.

7.† Show that a given lens must impress a given amount of convergence or divergence upon the rays which strike it near the edges.

8.† Show that the numerical sum of the reciprocals of any two conjugate focal lengths on opposite sides of a lens, or the numerical difference of two conjugate focal lengths on the same side of a lens must be a constant quantity. (Q. 7).

9. Find the index of refraction, I, of a double convex lens with two equal radii of curvature, R, and any two conjugate focal lengths, F and f. Prob. Q. 5 and 8.

10.† Find a general relation between the principal focal length of the lens in Q. 9, and any two of its (real) conjugate focal lengths. Prob. Q. 2 and 8.

11.† Show that the expression in Q. 10 can be extended to the case of any lens, converging or diverging, and to virtual as well as real focal lengths, and state when these are to be considered positive, and when negative.

12.‡ Describe one or more experiments illustrating the laws of (real) conjugate foci.

13.‡ Explain the location of the virtual images of lenses (by the method of parallax).

14.† Under what circumstances is a lens said to have two virtual conjugate foci?

15.‡ Describe one or more experiments illustrating the action of air lenses sourrounded by water.

16. By what kinds of lenses are convergence and divergence, respectively, produced? Q.

17.† Describe a construction for locating the image of an object formed by any lens with known optical centre and principal focus, and compare this with the corresponding construction for mirrors.

18.*†When is the image formed by a lens erect? and when inverted? when is it real? and when virtual? and what relation exists between the conditions in question?

19. Find a relation between the diameters of an object and its image formed by a lens and their distances from the lens, and compare the result with that obtained in the case of mirrors. D. 971, 1008.

20. Express the relative diameters of an object and its image thrown by a lens upon a screen in terms of the relative distances (1) of the object and lens (2) of the image and lens, and (3) of the object and image from the principal focus of the lens.

21. How far would you place (1) an object or (2) a screen from a lens of 16 cm. principal focal length, in order that the linear dimensions of an object may be enlarged 4 times? 8 times? 16 times? in order that they may be reduced in the ratio 2/1? 4/1? etc. Prob. Q. 20.

22.† Show that the virtual images formed by converging lenses are larger and those of diverging lenses smaller than the objects. (Q. 17).

23.† Why do converging lenses seem in certain respects to bring objects nearer to us, while diverging lenses seem to carry them farther away?

24. Show that in reality the virtual images formed by converging lenses are farther from them, and those formed by diverging lenses nearer to them than the objects. Q. 19, 22.

CXLVIII.

GENERAL PROPERTIES OF IMAGES.

1.† Explain the generality of the application of the laws for conjugate focal lengths to all optical combinations which have the property of imposing a constant amount of convergence or divergence upon the rays which strike just within their limits. (Q.)

2. Show that the same construction, with slight modifications, will serve to locate images in mirrors and lenses. Prob. Q.

3. Show that real images are always inverted, and virtual images always erect. Q.

4. Show that the diameter of an image is generally proportional to its distance, and inversely proportional to the distance of the object from the combination (or from the optical centre of the combination) by which it is produced, regardless of the nature of this combination. Prob. Q.

5. Show that virtual images formed by converging combinations are always larger and farther away ; by diverging combinations, smaller and nearer than the objects. Q.

6. Show that the areas of an image and the object are to each other (1) as their respective distances from the principal focus of the combination producing the image, (2) as the squares of their respective distances from the optical centre of this combination, (3) as the squares of the distances of the image and the combination from the principal focus, or (4) as the squares of the distances of the combination and the object from the principal focus. Prob. Q.

7.† Upon what three factors does the brightness of an image depend ?

8. State a general law connecting the area and the brightness of an image when greatly enlarged.

9. Show that the law in the last question does not apply to images which are considerably smaller than the objects which produce them.

10. Show that an image cannot be brighter than the object by which it is produced.

11. Describe and explain one or more experiments illustrating the relative brightness and angular limits of visibility in images thrown upon a white screen (whether seen by transmitted or by reflected light) as compared with images formed in mid-air. D. 973, Q. CXXX., 16.

12. What is meant by a visual angle? by the angular diameter of an object? by the magnifying power of any optical combination? D. 1026.

CXLIX.

MAGNIFYING GLASSES.

1. What is meant by a magnifying glass? by a simple microscope? (by an eye-piece?) D. 1028.

2.† Show that a lens does not magnify an object at a *fixed distance* if it is held (1) close to the eye or (2) close to the object.

3.‡ Describe one or more experiments showing the best position of a lens of feeble magnifying power with respect to objects at a fixed distance from the eye. (D. 1028).

4.† Upon what does the utility of magnifying glasses depend?

5.† How far from the eye should a magnifying glass be held, and how far from the glass should an object be placed, in order that it may be magnified as much as possible? (D. 1028).

6.† What is meant by focussing the eye-piece (upon the cross-hairs) of an instrument?

7.† What in general is the first process of adjustment in any instrument provided with an eye-piece and cross-hairs?

8. Describe the use and construction of different kinds of spectacles.

9.† Explain how stereoscopic effects can be produced by a pair of drawings properly made, and how these effects may be improved by the use of a pair of ordinary (converging) spectacles.

10. Describe and explain the *essential* elements in a stereoscope. D. 1025, Q. 9.

CL.

CAMERAS.

1. Describe the construction of a photographic camera. D. 1018.

2.† State some of the difficulties which have been met in constructing cameras so as to give a clear image covering a wide visual angle. (Q. 3-6).

3. What is meant by "chromatic aberration," and how is it overcome? D. 1062-1064; Q. CXXXVI., 33.

4.† What is meant by "astigmatism," and how is it avoided?

5.† What is meant by "flatness of the field," and how can it be secured?

6.† Explain the distortion produced by a single lens with a "stop" (1) in front of it and (2) behind it.

7.† What is meant by "doublet," or a "rectilinear lens," and how is it usually constructed?

8.† What size of stop should be used (1) in focussing? (2) when rapidity is desired? (3) when the best definition is sought for? and why? (Q.)

9. What is meant by a camera obscura? D. 1017.

10. Describe the construction and use of (1) a projecting lantern and (2) a solar microscope. D. 1020.

11. Point out the structural similarity between different forms of camera and projecting apparatus.

12.† Describe and explain one or more experiments illustrating the advantage, for purposes of projection, of employing "slides" which are perfectly transparent in places. (Q. CLXVIII., 10).

13.† What relation should exist between the cone of rays issuing from the projecting lantern, and the opening of the projecting lens? and why?

14.† Why is an electric arc light preferable to a gas flame of the same candle power for purposes of projection?

15.† State one or more practical rules for the adjustment of projecting apparatus.

CLI.

TELESCOPES AND MICROSCOPES.

1.† How would you convert (1) a camera into a telescope? or (2) a projecting lantern into a compound microscope?

2.* Name the two essential parts in which (1) a telescope or (2) a microscope consists. D. 1029, 1030.

3.*†Show the structural similarity between an inverting telecope and a compound microscope. (Q.)

4.*†State the practical distinction between a telescope and a compound microscope.

5.* Illustrate, by diagrams, the shapes and positions of the lenses and of the real and virtual images in (1) an astronomical telescope, and (2) a compound microscope. Dr 1029, 1030.

6.† Where must the cross-hairs placed (1) in an astronomical telescope, and (2) in a reading microscope?

7.† Explain the ordinary process of focussing a telescope or a microscope, with cross-hairs, upon an object.

8. Upon what does the magnifying power of an inverting telescope depend? D. 1030.

9. State the dependence of the magnifying power of a compound microscope upon (1) that of its eye-piece, and (2) that of its objective, and the data which determine the latter. D. 1029.

10. Point out the essential parts of a reflecting telescope. D. 1034.

11.*†How can a telescope or a microscope be constructed with two lenses so as not to invert the images of objects?

12.† What is meant by a Galilean eye-piece? (D. 1033).

13.* Show by diagrams the position and shape of the lenses and images in a Galilean telescope, and state whether the images are real or virtual in each case. D. 1033.

14.* Can cross-hairs be introduced into a Galilean telescope so as to be visible, or not, and why? D. 1033.

15.* In what do ordinary opera-glasses consist? D. 1033.

16.* Show by diagrams the shape and position of the lenses and images in a spy-glass; and state whether the images are real or virtual, and erect or inverted in each case. D. 1032.

CLII.

SPECTROSCOPES AND SPECTROMETERS.

1.† Explain the production, by means of a prism and lens, of a highly refracted real image of a slit illuminated by monochromatic light.

2.‡ Describe one or more experiments showing that a clear focus is obtained, as in the last question, only when the prism is in the position of minimum deviation.

3.† Explain the production, as in Q. 1, of several images of a slit when illuminated by light due to different metallic vapors. (Q.)

4. Show that a prism cannot, at one and the same time, be in its position of minimum deviation for rays of different colors. Prob. Q.

5.‡ Describe one or more experiments illustrating the point in the last question.

6. Why cannot a clear spectrum be obtained by means of a single lens and prism? Q. 2, 4.

7.† How is the difficulty mentioned in the last question avoided?

8.† Explain the use of a collimating lens in spectroscopic work.

9. State and explain the advantage of making rays *parallel* before passing through a prism, and whether these rays are parallel after emergence (1) if they are of the same color and (2) if they are of different colors. D. 1054.

10. How are the different sets of parallel rays emerging from a prism, brought to a focus? Q.

11. What is the advantage of substituting an eye-piece for a screen in the examination of spectra? Q. CXLVIII., 11.

12. Name five essential parts of a spectroscope. Q.

13.† What is meant by the "collimator?" the prism? and the telescope of a spectroscope? (D. 1053).

14.† Explain the advantage of using a scale in connection with spectroscopic work.

15. How is the image of a scale brought into the field of view of a spectroscope? D. 1053.

16.† Draw a diagram of a modern spectroscope, showing the paths of two or more sets of differently colored rays.

17.‡ In what respects does a spectrometer differ from a spectroscope?

18.‡ Explain the measurement of angles of refraction by means of a spectrometer.

19.† How are indices of refraction of different kinds of glass for light of a given wave-length most accurately determined?

20.† Explain the use of a spectrometer for determining angles of diffraction.

21.‡ Describe one or more experiments showing that diffraction gratings have, like prisms, a position of minimum deviation.

22.† State certain advantages in determining the angles of diffraction of a grating in its position of minimum deviation.

23.† Find the wave-length, l, of light in terms of the distance, d, between the lines of a diffraction grating, and the angle, a, of minimum deviation.

24. Explain how wave-lengths of light may be accurately determined by means of a spectrometer. Prob. Q.

THE END.

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